

Waste Composting for Urban and Peri-urban Agriculture: Closing the Rural–Urban Nutrient Cycle in Sub-Saharan Africa

**Edited by
Pay Drechsel and
Dagmar Kunze**



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WASTE COMPOSTING FOR URBAN AND PERI-URBAN AGRICULTURE

**Closing the Rural–Urban Nutrient Cycle in
Sub-Saharan Africa**

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Edited by

Pay Drechsel

*International Water Management Institute (IWMI)
Subregional Office
Ghana*

and

Dagmar Kunze

*Food and Agriculture Organization (FAO) of the United Nations
Regional Office for Africa
Ghana*

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International Water Management Institute (IWMI)*

PO Box 2075

Colombo, Sri Lanka

Web site: www.IWMI.org

Food and Agriculture Organization of the United Nations (FAO)

Viale delle Terme di Caracalla, 00100 Rome, Italy

Tel: +39 06 57051 Fax: +39 06 57053152

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Contributors

- Abaidoo, R.C.** Department of Biological Sciences, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
- Adam, M.** Natural Resources Institute (NRI), Central Avenue, Chatham Maritime, Kent ME4 4TB, UK; present address: Gundulf's Meadow, 181 Offham Road, West Malling, Kent ME19 6RF, UK
- Agbola, T.** Center for Urban and Regional Planning, Faculty of Social Science, University of Ibadan, PO Box 26970, Agodi Post Office, Ibadan, Nigeria
- Allison, M.** Henry Doubleday Research Association, Ryton-on-Dunsmore, Coventry CV8 3LG, UK
- Amend, J.** Urban Vegetable Promotion Project, German Technical Co-operation (GTZ), PO Box 31311, Dar es Salaam, Tanzania
- Amoah, P.** International Water Management Institute (IWMI) (formerly of International Board for Soil Research and Management; IBSRAM), Ghana Subregional Office for West Africa, c/o Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
- Asante-Mensah, S.** Department of Agricultural Economics and Farm Management, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
- Awuye, J.A.** Accra Metropolitan Assembly (AMA), Waste Management Department (WMD), PO Box 1269, Accra, Ghana
- Binder, C.** Swiss Federal Institute of Technology (EAWAG), PO Box 611, CH-8600 Dübendorf, Switzerland
- Dalsgaard, A.** Department for Veterinary Microbiology, Royal Veterinary and Agricultural University, Thorvaldsensvej 40, DK-1871 Frederiksberg C, Denmark
- De Jager, A.** Agricultural Economics Research Institute (LEI), PO Box 29703, The Hague, The Netherlands

- Doucouré, D.** African Institute of Urban Management (IAGU), PO Box 7263, Dakar, Senegal
- Drechsel, P.** International Water Management Institute (IWMI) (formerly of International Board for Soil Research and Management; IBSRAM), Ghana Subregional Office for West Africa, c/o Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
- Eaton, D.** Agricultural Economics Research Institute (LEI), PO Box 29703, The Hague, The Netherlands
- Etuah-Jackson, I.** GROWTH Integrated Development Programmes (NGO), PO Box CT.4727, Accra, Ghana
- Færge, J.** Department of Agricultural Sciences, Royal Veterinary and Agricultural University, Thorvaldsensvej 40, DK-1871 Frederiksberg C, Denmark
- Harris, P.J.C.** School of Science and the Environment, Coventry University, Priory Street, Coventry CV1 5FB, UK; Henry Doubleday Research Association, Ryton-on-Dunsmore, Coventry CV8 3LG, UK
- Helbig, J.** Humboldt-University of Berlin, College of Agriculture and Horticulture, Department of Phytomedicine, Lentzeallee 55–57, D-14195 Berlin, Germany
- Henze, M.** Department for Environmental Science and Engineering, B 115, Danish Technical University, DK- Lyngby 2800, Denmark
- Kelley, J.** CABI Bioscience, Bakeham Lane, Egham, Surrey TW20 9TY, UK
- Kessler, A.** Humboldt-University of Berlin, Institute of Agricultural Sociology, Luisenstrasse 53, D-10099 Berlin, Germany
- Kiango, S.** Urban Vegetable Promotion Project, Ministry of Agriculture and Co-operatives, PO Box 31311, Dar es Salaam, Tanzania
- Kindness, H.M.** Natural Resources Institute (NRI), Central Avenue, Chatham Maritime, Kent ME4 4TB, UK
- Klaassen, W.P.** GROWTH Integrated Development Programmes (NGO), PO Box CT.4727, Accra, Ghana
- Kunze, D.** Food and Agriculture Organization (FAO) of the United Nations, Ghana Regional Office for Africa, PO Box 1628, Accra, Ghana
- Leitzinger, C.** Entsorgung + Recycling Zürich (ERZ), Baendlistrasse 108, CH-8010 Zurich, Switzerland
- Litterscheid, H.** GFA-Infrastruktur und Umweltschutz GMBH, Königs-wintererstrasse 827, D-53227 Bonn, Germany
- Magid, J.** Department of Agricultural Sciences, Royal Veterinary and Agricultural University, Thorvaldsensvej 40, DK-1871 Frederiksberg C, Denmark
- Mensah, E.** Agricultural Engineering Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
- Niemeyer, R.G.** GFA-Infrastruktur und Umweltschutz GMBH, Königs-wintererstrasse 827, D-53227 Bonn, Germany
- Nsiah-Gyabaah, K.** Sunyani Polytechnic, PO Box 206, Sunyani, Ghana

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- Oladokun, M.A.O.** Department of Horticulture, University of Agriculture, PM Box 2240, Abeokuta, Nigeria
- Patzel, N.** Swiss Federal Institute of Technology (EAWAG), PO Box 611, CH-8600 Dübendorf, Switzerland
- Penning de Vries, F.** International Water Management Institute (IWMI) (formerly of International Board for Soil Research and Management; IBSRAM), PO Box 9-109, Jatujak, Bangkok 10900, Thailand
- Quansah, C.** Department of Crop Science, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
- Salifu, L.** Urban Environmental Sanitation (Urban IV) Project, Kumasi Metropolitan Assembly, PO Box 1916, Kumasi, Ghana; present address: Water and Sanitation Program, Africa Region, The World Bank, PO Box 30577, Nairobi, Kenya
- Sanders, S.** GFA-Infrastruktur und Umweltschutz GMBH, Königswintererstrasse 827, D-53227 Bonn, Germany
- Sawio, C.J.** University of Dar es Salaam, PO Box 35049, Dar es Salaam, Tanzania
- Schreurs, M.E.A.** International Institute for Soil Fertility Management (IFDC-Africa), PO Box 4483, Lomé, Togo
- Smith, G.** Henry Doubleday Research Association, Ryton-on-Dunsmore, Coventry CV8 3LG, UK
- Spies, L.** Technikon Pretoria, PB X680, Pretoria 0001, Republic of South Africa
- Van den Bosch, H.** Alterra Green World Research, PO Box 125, 6700 AC Wageningen, The Netherlands
- Van Reuler, H.** International Institute for Soil Fertility Management (IFDC-Africa) PO Box 4483, Lomé, Togo
- Van Wijk, M.S.** Agricultural Economics Research Institute (LEI), PO Box 29703, The Hague, The Netherlands
- Vlaming, J.** Alterra Green World Research, PO Box 125, 6700 AC Wageningen, The Netherlands

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Pay Drechsel
Dagmar Kunze

Foreword

One of the greatest future challenges for governments all over the world will be the provision of nutritional and affordable food for expanding urban populations. On a global scale urban settlements consume currently 70–80% of all resources. This centralized consumption results in problems at both ends of the food chain: soil nutrient mining in agricultural production areas and pollution and waste disposal problems in urban centres.

Increasingly, municipal authorities are viewing the recycling of nutrients from organic waste through solid waste compost production (often mixed with sewage) as an integral part of their waste management schemes. In this way, the costs of waste management/disposal can be reduced and the nutrient cycle closed, to the benefits of urban and peri-urban farmers.

This requires an integrated and multidisciplinary approach that considers the different technical options and their economic feasibility, as well as the administrative framework and socio-cultural and environmental issues. Farmers' perception of the waste product as a benefit is as important as the potential contamination of the compost with heavy metals. All these aspects are discussed in this publication supplemented and illustrated with examples and case studies, mostly from Africa.

IWMI (formerly IBSRAM) and FAO are pleased to present this joint publication as a contribution to the discussion of these important issues.

Frank Rijsberman
IWMI

Bamidele F. Dada
FAO

Introduction¹

In sub-Saharan Africa (SSA) the majority of the population will be living in and around urban areas by 2020. Rapid urbanization has provoked not only major challenges to rural–urban planning with regard to urban food security but also in relation to waste management and environmental protection. The development of appropriate policy tools to support this process by minimizing its negative externalities has become increasingly important as policy-makers have started to respond to these geographical shifts. Although the creation of coherent and relevant policy advice is still in its infancy, there is increasing awareness of the challenges ahead and recognition of phenomena, such as urban agriculture, which can contribute directly and indirectly to several policy goals.

Food security

The contribution to urban food security is certainly the most important goal. But urban and peri-urban agriculture can also increase employment and income, which, in turn, will permit people to purchase or otherwise acquire food to increase their food security. Although cities in many parts of the world were established in the most fertile regions, their location vis-à-vis agriculture is usually incidental nowadays. This is especially so in SSA where colonially founded capitals were often developed along the coast, as transport nodes and/or administrative centres. Soil and water supply conditions may not therefore be intrinsically ideal for crops, and bulk food production may well be at some distance from the cities. Thus, (peri-)urban agriculture may be more

¹The text draws from a workshop keynote given by Chris Lewcock, formerly Natural Resources Institute.

significant for urban food security through a series of niche contributions that have a combined significance than through its contribution to aggregate urban food supply. These niche contributions include the production of highly perishable market products such as milk, green leafy vegetables, eggs, etc., as well as the production of subsistence crops in home gardens, but can also comprise the provisioning of food in emergencies, e.g. in economic depression or wartime. Therefore, agricultural development proposals for urban and near-urban areas should be focused on responding to carefully identified priority niche concerns.

Environmental protection

Urban and peri-urban agriculture offers the potential for a classic win–win situation in which one of the major urban management problems, i.e. waste disposal, can be tackled at the same time as increasing food security through exploitation of the nutrient potential of the ‘wastes’. Unlike refuse in rural areas, urban household and market refuse is usually lost, contributes to urban pollution, or is used as landfill, meaning there is little or no return of biomass or nutrients to the production areas. The results are problems at both ends of the food chain: soil nutrient mining in rural and peri-urban production areas and pollution or waste problems where nutrients and other inputs accumulate (Fig. I.1).

However, it cannot be assumed that simply turning waste into compost and making it available to farmers is effective. As several contributions in this publication will point out, the raw wastes or composts may not be well located in relation to the farmers who require them, they may have high production/transport/labour costs, they may not have the correct characteristics for the crops chosen, the farmers may be unfamiliar with their use, and even if exploited to the maximum they may not prevent long-term fertility decline in intensively used soils. Moreover, there can be high environmental and health risks from farming with recycled wastes or wastewater, both from crop contamination and from the damage that intensive use of agricultural inputs might do to the environment. Therefore, it appears necessary to develop integrated nutrient strategies tailored to city specific situations. This certainly includes consideration of farm and soil types, water supply, manure and inorganic fertilizer availability, as well as a range of other biophysical and socioeconomic conditions.

Implementation in the urban–rural context

One of the key concerns should be that any solutions we devise can be effectively implemented. This is not just a matter of technical feasibility. It is governed essentially by the capacity and will of a bewildering variety of institutions and individuals who have to choose to support or take up the solutions. The task of developing and promoting relevant approaches to near-urban natural resource

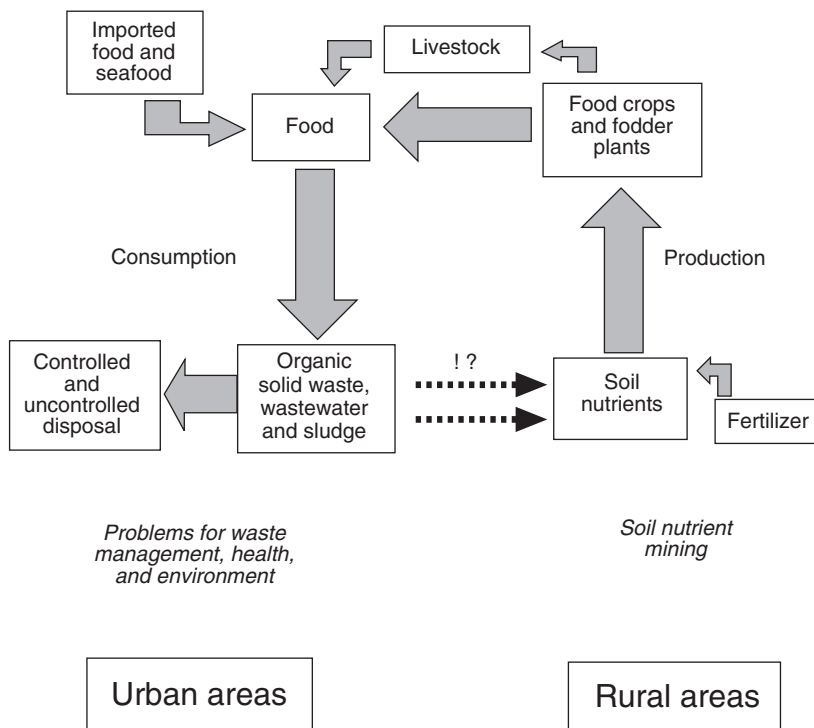


Fig. 1.1. Urban centres are vast nutrient sinks. Agriculture, especially in the rural–urban interface (the peri-urban area), could benefit from nutrient recycling (Drechsel *et al.*, 1999, modified).

management is doubled in complexity because of the gulf which generally exists between urban and rural administrative, scientific and sociocultural perspectives. Therefore, it will be a challenge for urban and rural managers, scientists and policy makers to broaden their horizons, and to share and adapt their respective knowledge and policies.

This publication should contribute to this process. It contains state-of-the-art reports and case studies that focus on: (i) urban and peri-urban agriculture and farming systems; and (ii) environmentally safe nutrient recycling options from organic waste generated in cities for use by urban and peri-urban farmers. The reports address technical, biophysical, socio-economic and administrative circumstances. For the first time, different approaches to quantify urban nutrient balances and rural–urban nutrient flows are presented. Special reference is given to West and East Africa, with acknowledgement of experiences from other parts of the world.

Most of the chapters accepted for this publication are derived from an international workshop organized jointly by the International Board for Soil Research and Management (IBSRAM) and the Food and Agriculture Organization (FAO) of the United Nations in 1999. The workshop took place

in Accra, Ghana, with the Accra Metropolitan Assembly (AMA) as local co-host. Participants came from 15 countries, covering a broad range of disciplines as well as national and international institutions (Drechsel and Kunze, 1999).

This meeting followed two national events initiated by FAO and the Natural Resources Institute (NRI), respectively. While the FAO–AMA seminar had its focus on urban food supply and marketing (Sackey, 1998), the NRI workshop inaugurated the Department for International Development-funded Peri-urban Interface project located in Kumasi (NRI, 1995). This project produced a wealth of information and data on peri-urban agriculture and related issues, probably unique in the developing world. Several chapters in this book draw from this experience. However, the venue was not only chosen because of its proximity to Kumasi, but also due to Ghana's comparatively pioneering commitment to both urban agriculture and organic waste recycling. This was confirmed in the opening addresses of the Honourable Minister of Food and Agriculture, Mr J.H. Owusu-Acheampong and the Mayor of Accra, Mr Samuel V.A. Addo, who both acknowledged the role and importance of urban and peri-urban agriculture. The Minister furthermore urged the participants 'to explore possibilities of transforming the huge quantities of organic wastes, which accumulate in the cities into soil amendment inputs such as organic fertilizers for improvement of soil fertility and environmental sanitation'. This book summarizes related experience with consideration of its socio-economic, scientific and environmental dimensions. To suit the overall structure and emphasis, it became necessary to revise and shorten several of the chapters submitted; we are grateful to all authors for their cooperation.

Pay Drechsel
Dagmar Kunze

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The Potential Use of Waste-stream Products for Soil Amelioration in Peri-urban Interface Agricultural Production Systems

P.J.C. Harris^{1,2}, M. Allison², G. Smith²,
H.M. Kindness³ and J. Kelley⁴

¹*School of Science and the Environment, Coventry University, Coventry, UK;* ²*Henry Doubleday Research Association, Ryton-on-Dunsmore, Coventry, UK;* ³*Natural Resources Institute (NRI), Chatham Maritime, Kent, UK;* ⁴*CABI Bioscience, Egham, Surrey, UK*

This chapter discusses the opportunities and constraints that influence the use of organic waste-stream products for soil amelioration. The information is given as a checklist to aid decision-making, illustrated where possible by examples from developing countries.

Key words: waste management, soil management, urban agriculture, farming systems

Introduction

In 1996, The Henry Doubleday Research Association was contracted to carry out a desk review for the UK Overseas Development Agency (now Department for International Development – DFID) on ‘The use of urban waste in peri-urban interface production systems’ (Allison *et al.*, 1998). This review had an international rather than a country-specific focus although most of the examples cited were from developing countries. The review formed part of a strategy ‘to develop and promote cost-effective techniques for recycling/processing organic waste for use as a fertilizer’ and contributed

to the wider goal 'to increase productive potential by greater use of waste materials and recycling of resources'. The conclusions of the review were further developed in connection with an International Mycological Institute project on 'The Use of Composted Urban Wastes in Integrated Management Systems to Control Pests and Pathogens in Peri-urban Agriculture' which was funded by the Crop Protection Programme of DFID and studied the potential value of municipal compost for crop production in peri-urban Kumasi, Ghana (Harris and Smith, 1997; Anon., 1998). Finally, the concepts were refined as an input to a third study 'Kumasi Natural Resources Management Research Project' funded by DFID and coordinated by the Natural Resources Institute (Harris and Smith, 1998).

The objective of this chapter is to synthesize the information from these earlier studies in the form of a checklist to aid decision making.

Checklist for Analysing the Potential Use of Waste-stream Products in the Peri-urban Situation

Figure 1.1 shows a checklist for analysing the potential use of waste-stream products for soil amelioration in peri-urban interface agricultural production systems. Many of the questions posed will be common to all potential organic soil ameliorant materials considered for a particular location, clientele or purpose, but some questions will require answers for each potential material considered. The checklist is made up of the following categories, although in reality the analytical process is not a simple linear one:

- the nature, source and supply, and potential of the raw waste (Items 1–8);
- alternative uses of the waste (Items 9–12);
- quality and management of the waste (Items 13–24);
- processing of the waste (Items 25–32);
- demand for, and end use of, the waste or waste products (Items 33–42).

1. What wastes are available?

Within the urban and peri-urban situation, the concept of waste is often that of an otherwise 'useless or discarded material'. Such accumulated material may cause health, safety, environmental and aesthetic concerns, and may represent a problem requiring safe disposal. However, in one sense a material is only a 'waste' if it is useless; as soon as it is usable it becomes a 'resource'. Thus the same output of a process may be considered a waste if it has no further use, but a valuable by-product if it is used. While some of the materials considered for soil amelioration in this report are clearly wastes at present (in surplus, otherwise unused, and often presenting a disposal problem), others are by-products for which soil amelioration is but one of a range of potential uses. The supply of poultry manure is reported currently to be greater than

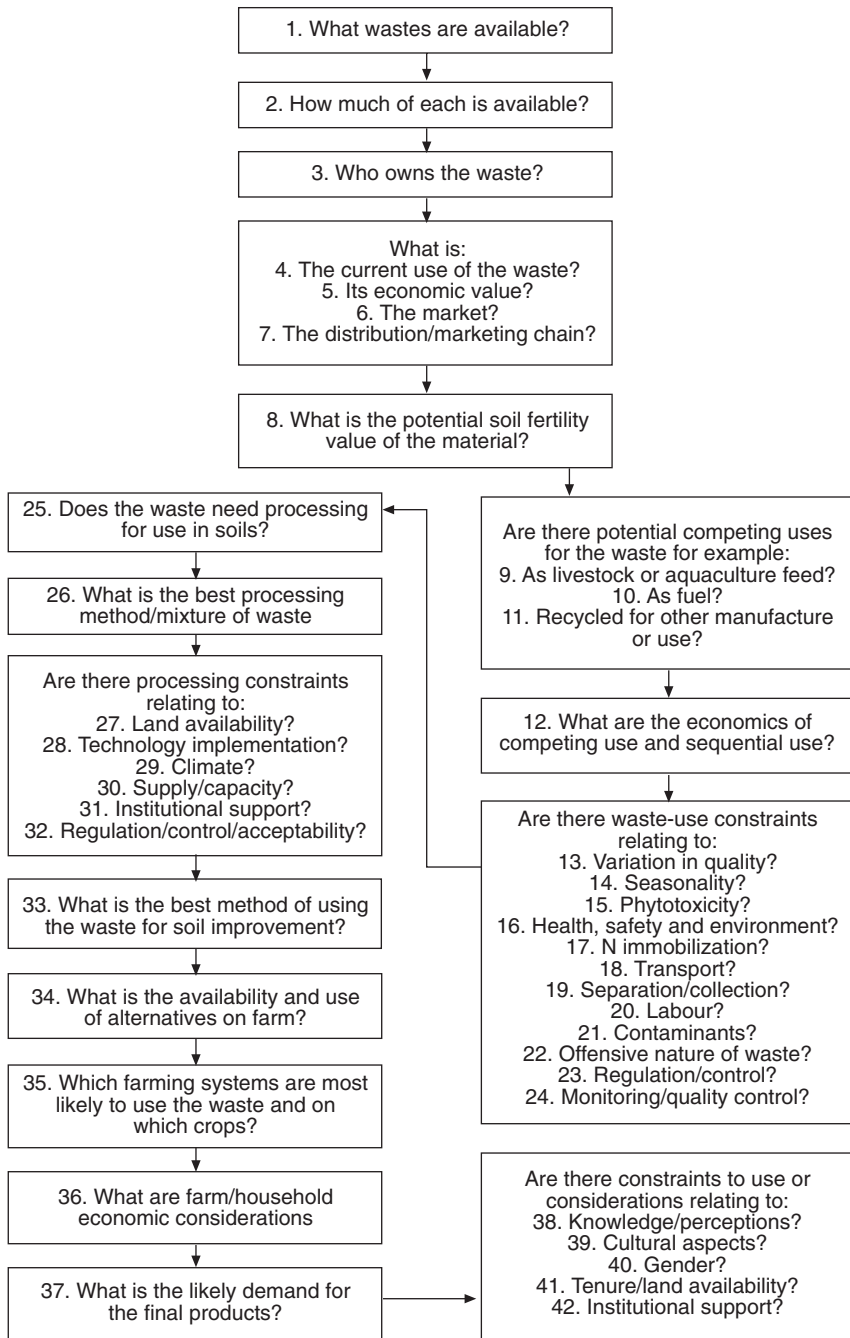


Fig. 1.1. Check list for analysing the potential use of waste-stream products in the peri-urban situation.

demand around Kumasi, Ghana. 'Poultry manure is dumped and sometimes burned by road sides in peri-urban Kumasi and its abundance creates a problem for poultry farmers' (Quansah *et al.*, 1997). Kindness (1999) reported that 84% of poultry manure is used in farming in peri-urban Kumasi and 15% is dumped and burnt.

Important organic materials include municipal waste, night-soil and sewage sludge, livestock manures, and agro-industrial wastes from crop processing and livestock. Municipal waste including domestic, industrial and commercial wastes in various proportions usually has a high organic content in developing countries. Salvage and recycling of metals and other materials of value is common in many developing countries and partly accounts for the high organic content of wastes, for example 87% in Accra and 75% in an Indian city, compared with 3–16% in a northern European city (Dalzell *et al.*, 1987; Deelstra, 1989).

In urban areas, large quantities of human excrement are generated. Night-soil is the term used for the mixture of human faeces and urine that accumulates in waterless sanitation systems. Seventy per cent of urban dwellers in developing countries are not on a sewerage system. Thus, in much of the world sewage is not water borne but exists as night-soil. Generally urban dwellers have access to pit latrines (80% in Dar es Salaam, Muller and Rijnsburger, 1994). Where treatment facilities exist, sewage sludge is produced.

Urban and peri-urban livestock enterprises, producing livestock outputs in great and increasing demand by urban populations, are producers of surplus animal manures because of intensification of the production systems, particularly for poultry and dairy production. There is thus less opportunity to dispose of manure on land held by the livestock producer. Livestock manure is also generated by the movement of animals from rural to urban areas for slaughter, sometimes with relatively brief 'finishing' of the animals in peri-urban areas.

In cities in developing countries, significant quantities of organic wastes are generated by agricultural processing enterprises. In practice, an audit of every processing operation in an area should be carried out to assess whether under-used by-products exist and whether soil amelioration is an option for use. For example, Kindness (1999) quantified the availability of municipal waste, night-soil and sewage sludge, black soil and livestock manures in Kumasi but also identified sawdust, slaughterhouse wastes, brewery waste, oil palm waste, cocoa waste and cassava peel as potential soil ameliorant resources in peri-urban Kumasi.

2. How much of each is available?

Estimates for total waste generation in cities vary, particularly in cities where much of the waste is not collected and the population of the city is growing rapidly. Estimates suggest that Metro Manila with 12 million people generates

4000 t of waste day⁻¹ (Medina, 1993), Jakarta with a similar population produces 5000 t day⁻¹ (Simpson, 1993), Dar es Salaam with about 3 million people generates 740 t of organic waste day⁻¹ (Lopez-Real, 1995a), Calcutta with 10 million people produces 3000 t day⁻¹ (Kundu, 1995), and Kano with 1.4 million people generates 450 t day⁻¹ (Lewcock, 1994). Estimation of waste production from specific agro-industries or particular sectors, such as market waste, may be easier but few studies have attempted to provide anything other than wide-range estimates.

3. Who owns the waste?

In the first instance the producer owns the waste. However, since 'waste' varies from a valuable resource to a major disposal problem, ownership can be seen in positive and negative terms. Not surprisingly, the greater the value of the waste, the more interest there is in ownership, and conversely, the greater the supply or magnitude of disposal problems, the less desire there is for ownership, which has sometimes to be enforced by regulation under the same principle as 'polluter pays'.

There are many different models of ownership and transfer of ownership. The most relevant of these are given in Table 1.1. This list refers mainly to materials suitable solely for soil amelioration and more complicated arrangements exist when recycling of other materials such as glass, metal and wood is considered. Then, the 'ownership' models do not represent exclusive options.

4. What is the current use of the waste?

Although there are examples of very efficient waste recycling through collection, scavenging and processing with a high proportion of reuse of a wide range of waste types (Allison *et al.*, 1998), in many cases the lower value wastes such as municipal refuse remain underused. In developing countries where cities have grown rapidly and there is not enough money for environmentally sound waste disposal, a large proportion of the waste that is collected is dumped in abandoned quarries or wetlands near to the city. In Brazil it has been estimated that 76% of the 90,000 t of waste generated day⁻¹ is disposed of in this way (Wells, 1995). Deelstra (1989) estimated that 90% of all waste from cities in developing countries is dumped when over 60% of it could be recycled.

5. What is its economic value?

It cannot be assumed that agriculture is the most economic or desirable use for all urban organic wastes. There may also be alternative uses of a waste material within agriculture, with economic factors dictating whether a particular

Table 1.1. Selected models of ownership for wastes as soil ameliorants.

Ownership model	Examples
● Producer uses the waste	● Home/community composting of domestic wastes ● Use of manures and crop residues on peri-urban farms ● Use of agro-industrial wastes on commercial farms and plantations
● Producer dumps the (relatively low value) waste which becomes common property	● Domestic waste where municipal refuse collections are absent, inadequate or offer incomplete coverage ● Animal manures that are dumped and free to anyone who will collect ● Industrial wastes such as sawdust which have little commercial value
● Producer sells the (relatively high value) waste to an end user; likely to be a farmer, but garden centres and private or public amenity horticultural projects are also purchasers	● High value by-products such as oil palm wastes, which often have alternative uses for animal feed, fuel, etc. ● Animal manures
● Producer sells the (relatively high value) waste to an intermediate user interested in adding value to the waste by processing and/or re-sale	● Most commonly waste for re-sale as animal feed or fuel, but also for soil amelioration
● Producer gives the (relatively low value) waste to, or pays to have it removed by, a contractor or public body ● The waste becomes common property ● The waste is sold, or its exploitation licensed ● Unofficial 'owners' sell the waste to end users	● Usually municipal waste, but also agro-industrial wastes ● The collector permits scavenging of the waste, and may see this as a service in recycling and reducing disposal problems ● The collector retains ownership and sells the waste or a fraction of it, or controls access to scavenging and exploitation through licensing ● Low value waste that is dumped but unofficially sold by waste management officials accepting payments or by truck drivers diverting waste to end users

waste is used for fodder or fuel rather than fertilizer. Such decisions will affect various sectors of society differently. The purchase of livestock feed may allow more return of crop residues to the soil; the degree of access to a range of fuel sources may determine whether livestock manures are used as fuel or fertilizer.

Some by-products are less 'waste' than others, for instance cocoa bean shells and cotton seeds are exported to Europe from Ghana (Owusu-Bennoah and Visker, 1994) and this is reflected in their value. Wastes that occur in a 'pure' form rather than as an element in domestic refuse are likely to have a higher value since they are more likely to be used as, for example, livestock feed.

There is a need for detailed economic analyses of the value of wastes, especially studies that include the economic value, which could be given to the fertilizer value and longer term soil amelioration properties of waste products, and to disposal/environmental/health aspects in a cost-benefit analysis.

6. What is the market?

A limited amount of information exists on the influence of markets on the collection, processing and use of urban wastes for agriculture. In some cases there is evidence of trade in raw waste materials and this has been surveyed recently for Kumasi by Kindness (1999). The majority of documented cases, however, concern the successes and failures of institutionally organized large-scale schemes for processing urban organic waste. There are many reports of the cost of producing compost for soil amelioration exceeding its value. There are, however, also documented cases of successful viable markets for composts (Allison *et al.*, 1998). In Mali, Lardinois and van de Klundert (1994a,b) report that the reliable supply, low selling price, and proven quality as a soil conditioner have created a high demand from vegetable farmers for compost dug as black soil from municipal dump sites. There is a market for animal manures, often transported over considerable distances in Kenya (Lekasi *et al.*, 1998) and for poultry manure from intensive poultry farms in Nigeria and other countries (Opara and Asiegbu, 1996).

7. What is the distribution/marketing chain?

Clearly there are many different stakeholders involved in the waste stream in urban/peri-urban areas. Producers may be individual households, commercial or industrial producers, or public institutions such as hospitals and schools. Collectors/processors may be individuals, communities, cooperatives, non-governmental organizations (NGOs), commercial enterprises, or public waste management departments. Users may be individual farmers, communities, cooperatives or commercial plantations.

Waste collection tends to be the responsibility of municipal authorities. However, waste management can also involve a combination of public and private activity or be solely private. Furedy (1992) describes composting in Jakarta, supported by the municipality. The composting agents were private individuals involved in the waste trade, rather than government officials.

8. What is the potential soil fertility value of the material?

The nutrients contained in waste may be a major reason for applying it to crops, and nutrients will be mineralized gradually and become available. There is considerable variation in the nutrient content of municipal wastes. The values are probably most similar to the values for composted material cited in Cross and Strauss (1985), 0.4–3.6% N, 0.3–3.5% P_2O_5 , and 0.5–1.8% K_2O , while Gaur and Verma (1991) state that Indian municipal wastes contain 0.5% N, 0.3% P, and 0.3% K.

The nutrient content may not, however, be the most valuable gain from addition to soil. Organic matter is necessary to maintain soil structure and provide an aerated yet moisture retentive environment for optimum root growth. Thus, the benefits of using organic materials for soil improvement result from increased water infiltration of the soil, its increased water-holding capacity, improved aeration and permeability, soil aggregation and rooting depth, and from decreased soil crusting, bulk density and runoff.

Organic waste material or compost is often applied to the growing crops as mulch where it has a beneficial effect in reducing weed growth. Compost and compost leachates also have an inhibitory effect on soil-borne pathogens (Hoitink *et al.*, 1997) either by enabling the plant to overcome sub-clinical root damage or more probably by allowing increased microbial activity to take place in the rhizosphere and soil zone around the plants, thereby encouraging microfloral antagonism to the growth of pathogens. Nematode populations may be decreased also (Gallardo-Lara and Nogales, 1987).

In Kenya, the value of manure is approximately five times that of its chemical fertilizer equivalent value (Lekasi *et al.*, 1998). This is presumably related to the effect of manure on the physical properties of soil as well as its role in plant nutrient supply. Elsewhere the long-term value of organic soil amendments may be less well understood.

9. Are there potential competing uses for the waste as livestock or aquaculture feed?

The fraction of the waste that is potentially valuable for soil amelioration may have alternative uses for animal feed, fuel or construction. Soil amelioration is often considered the least economic of the alternatives. In Senegal, crop residues are reported to be too valuable as animal feed to be used as fertilizer or for composting, while in Uganda, the poultry manure that is available is mixed with brewery waste and used as a cattle feed rather than as a fertilizer (Harris *et al.*, 1997). Municipal refuse is a significant source of food for urban livestock in many developing countries (Allison *et al.*, 1998).

Excreta added to aquaculture ponds stimulates growth of algae and thus the next link in the food chain such as rotifers and crustaceans that serve as fish food. McGarry (1976) points out that night-soil also acts as a direct fish

food. Yeung (1986) reports that 50–90% of the food fish in China come from waste-fed ponds.

10. Are there potential competing uses for the waste as fuel?

Fuel, like soil amelioration is often not considered a high value use of wastes but may be the chosen use where:

1. A shortage of alternative sources leaves little realistic choice other than the use of crop residues and/or animal manures for fuel. This situation is common in India and parts of Africa.
2. For reasons of convenience and fuel economy, the wastes may be used to produce biogas.
3. Use of agricultural residues such as bagasse, straws and husks as a fuel is often the most cost-effective management option for processing industries.

11. Are there potential competing uses for the waste recycled for other manufacture or use?

In most countries, waste paper has a higher value for production of paper than for livestock fodder or use as bedding, let alone as a soil ameliorant. Building blocks and boards can be made by incorporating agricultural fibre wastes such as straw. Cow manure is used as plaster for houses and straw is used for thatching, packing material or animal bedding. Paper can be produced from a wide variety of fibrous wastes. Craft items such as mats, hats and baskets can also be made from fibrous wastes. Maize stalks, rice husks and groundnut shells can be used for production of a wide range of products such as sugars, alcohols, furfural and cellulose derivatives, but this is seldom economic and seldom takes place in developing countries. With animal wastes, gelatine, glue and brush bristles can be obtained from animal body parts.

12. What are the economics of competing use and sequential use?

Sometimes it is not simply a question of single alternative uses for a waste, but a sequence of different uses, with soil amelioration at the end of the chain. For example, in West Bengal (Harris, 1996), rice straw is used as a thatch. When, at regular intervals, the thatched roof is replaced, the rotten straw is added to a compost heap but the better straw is fed to livestock. The manure from the livestock is added to the compost heap or applied directly in the field. Honghai and Veeman (undated) described a system in China whereby crop organic wastes are used as livestock fodder, the manure is used to produce biogas from which the effluent is used as a substrate for mushroom crops, with the spent mushroom compost used as a soil ameliorant.

There are few detailed economic studies of the alternative uses of wastes which are frequently not part of a cash economy. Some waste is recycled within a farm. Other waste is essentially 'free', as when livestock browse on domestic and market waste, but nevertheless very important to the household economy. The current pattern of use has evolved according to market forces and differs considerably from place to place. The use depends to a large extent on the local cost and availability of alternatives to each use.

13. Are there waste-use constraints relating to variation in quality?

Because of the variable nutrient content of urban refuse compared with compost that a farmer may have prepared from a single or small number of plant species plus manure, it may be difficult to estimate appropriate application rates. Farmers near Ho Chi Minh City, Vietnam were reported to err on the side of caution and over-apply additional inorganic nutrients (Jansen *et al.*, 1995).

14. Are there waste-use constraints relating to seasonality?

Composition of waste, particularly the organic components, varies from season to season (Samsunlu, 1982; Deelstra, 1989), again making it difficult to recommend exact application rates. Ishida (1989) found in Japan that whereas the demand for sewage sludge compost was seasonal, the supply was all year round and this led to problems of storage and maintenance of quality.

15. Are there waste-use constraints relating to phytotoxicity?

Garcia *et al.* (1992) showed that fresh sewage sludge and urban waste had severe inhibitory effects on seed germination. Phytotoxicity, in addition to that caused by ammonia 'burning' of crops, was due to excessive electrical conductivity, phenolics, and low molecular weight organic acids. Composts that are not thoroughly stabilized can also cause intensely reducing anaerobic conditions around the plant roots.

16. Are there waste-use constraints relating to health, safety and environment?

Wastes collected, processed or used close to streams may cause pollution; close to housing they may cause offence. Any waste made up of, or containing, human faecal material poses a health hazard from pathogens unless properly processed. It may be that the risk, or the cost of reducing the risk to

an acceptable level, of the use of some wastes outweighs their soil amelioration value. This might apply, for example, to biomedical wastes. A major problem in developing countries is frequently that source separation of high risk wastes does not take place and this can compromise the safety and value of mixed bulk wastes.

A further fear relating to urban waste and compost is that crops will accumulate high levels of heavy metals. However, Drescher (1994), studying vegetables growing on an urban landfill site in Lusaka, Zambia, found that vegetables did not accumulate heavy metals. Even in heavily contaminated soils, concentrations of metals in the vegetables remained considerably lower than soil concentrations. Possible contamination of urban wastes with genetically modified organisms has been expressed recently as a new concern in organic agriculture in the UK.

17. Are there waste-use constraints relating to N immobilization?

Inappropriate use of wastes with high C:N ratios as soil improvers can lead to reduced soil fertility. Inhibitions of crop growth and development can be caused by nitrogen immobilization that may occur when fresh organic material containing relatively low amounts of nitrogen such as rice straw or sawdust is applied to soils (Garcia *et al.*, 1992).

18. Are there waste-use constraints relating to transport?

The nature of some raw wastes such as citrus pulp, with a large water content, makes it too heavy to transport economically. The constraints of transport are cited as one of the advantages of centralized composting of municipal wastes to produce soil improvers. It is probably more practical than taking the waste from the city to farmers, expecting that they will separate the wastes, compost the organics and leave the non-compostables for re-collection by the municipality. Even after processing organic waste into compost, it is bulky and of low value and this can geographically limit the size of potential markets. Lardinois and Van de Klundert (1994a,b) reported that use of urban compost around Asian cities was limited to a range of 25 km.

On a local scale, even if suitable processed waste is available, farmers themselves may lack appropriate transport. Maxwell and Zziwa (1992) found, among other constraints, that farmers in Kampala had difficulty transporting the waste to their plots. Problems related to transport of poultry manure in Ghana include both the cost of transport of poultry manure to the farm and the general transport of manure around the farm. Often distances from the household to the farm are large and the use of any form of draught power or ownership of implements such as wheelbarrows is small or non-existent. Also, paths are easily overgrown making access difficult (Harris *et al.*, 1998).

Transport costs and difficulties may determine the most appropriate processing strategy. For example, a dry fertilizer can be produced by sewage de-watering, mixing with waste or straw, and leaving to ferment anaerobically for about 3 weeks before drying, granulating and packing (Bo Ling, 1994). This dry fertilizer is popular because it is easy to transport and handle.

19. Are there waste-use constraints relating to separation/collection?

While recycling of the waste starts as soon as it is generated, as door-to-door collectors may buy the more valuable items from householders, the actual collection and transport of the waste is usually municipal. Devising a collection system that minimizes contamination is of primary importance. Although poor neighbourhoods have an urgent need for waste services, in Asia, NGOs are finding it more effective to work in middle and upper class areas. Source separation and decentralized composting are more worthwhile and feasible in such areas because the wastes contain more recyclables, the householders better understand the purposes of waste separation, they can pay for collection services and there is space for composting (Furedy, 1992).

20. Are there waste-use constraints relating to labour?

One of the most frequently cited constraints to on-farm recycling of wastes is that of labour to make compost or, if purchased, to transport, spread and incorporate it (Harris *et al.*, 1998). Even simple re-use of crop and livestock residues is labour intensive and direct incorporation of residues into the soil is hard work.

Farmers in the highlands of Guatemala used compost but, the value of labour expended making and using compost was higher than the cash outlay for a smaller equivalent weight of chemical fertilizer (Vogler, 1991). However, it should be noted that compost will improve the soil structure more, in the long term, than chemical fertilizers and the value of a farmer's labour is only relevant if he has the opportunity of alternative work to earn income. If no cash is available he cannot buy chemicals and organic composting is one of the few options for improving the fertility of his land.

21. Are there waste-use constraints relating to contaminants?

Probably the greatest problem for producers of compost from urban waste all over the world is contamination with inorganic materials. Devising a collection system that minimizes contamination is of primary importance. Picking is becoming increasingly hazardous as waste now contains more broken glass, toxic materials and biomedical waste. The presence of glass in the resulting compost was cited as one of the reasons why the products of com-

posting plants established in Indian cities such as Calcutta, Madras, Delhi and Bombay were unpopular (Jalan *et al.*, 1995). Farmers found that compost prepared in Bangkok contained plastic and glass, and barefoot paddy farmers were, unsurprisingly, not prepared to use it (Anon., 1979).

22. Are there waste-use constraints relating to offensive nature of waste?

In a number of countries the production and use of composted wastes has been rejected by potential users. In Bangkok hauliers refused to loan vehicles for the transport of compost because of this (Anon., 1979). There are also cultural constraints on the use of night-soil in parts of Africa (Cline-Cole, University of Birmingham, UK, personal communication, 1996), but Owusu-Bennoah and Visker (1994) report that in Ghana farmers were hijacking septic tank emptying vehicles in order to release the raw night-soil over their fields.

23. Are there waste-use constraints relating to regulation/control?

Urban authorities may have restrictions enforced by planning, environment or public health departments that limit the areas that could be used for waste collection, storage and processing. According to the district planners in peri-urban Kumasi, the siting of waste dumps is supposed to be decided by the assembly man and the community, with advice from Town and Country Planning, but no guidelines exist. It is a different department, the Environmental Health Office, which is responsible for waste disposal (Blake *et al.*, 1997). Although assistance from all sectors in dealing with low value surplus wastes is usually appreciated, conflicts can arise when small enterprises, communities or NGOs attempt to assume responsibilities which local government authorities consider their own.

24. Are there waste-use constraints relating to monitoring/quality control?

In developed countries there are regulations controlling the quality, description, and advertising of most products including proprietary soil ameliorants. Some similar regulations may apply in developing countries. The ability to monitor and control quality, with important implications for recommended application rates, may well be limited by inadequate or expensive analytical facilities in poorer countries.

25. Does the waste need processing for use in soils?

In some cases urban waste, including household refuse, is used directly for agriculture (Anon., 1991; Mortimore, 1993; Lewcock, 1994). However, as

described above, the use of 'raw' urban wastes can lead to problems with inert contaminants, health risks and N-immobilization. In most cases, organic wastes for use as soil improvers are processed before use. This may consist of simple sorting or source separation, or of further processing. The most common means of processing is composting. Because the composting process results in significant nutrient losses, raw wastes are actually of higher nutrient value for use as fertilizers but composting organic wastes before using them: (i) sanitizes waste, the high temperatures achieved during composting are very important for sanitizing compost, weed seeds are also destroyed; (ii) reduces waste volume, weight and water content and provides a stabilized product particularly from the point of view of nitrogen delivery; and (iii) alters the composition of waste, making it more suitable for agricultural use, thereby overcoming problems of phytotoxicity.

26. What is the best processing method/mixture of waste?

Mixtures of materials

It is desirable to mix materials for composting in proportions that give rapid, effective and complete decomposition to a stable product. Thus the range and supply of different materials may need to be considered in a waste management strategy for soil amelioration. For example, night-soil can be processed by mixed composting with domestic wastes in windrows. Reporting on the potential for composting in Kumasi, Lopez-Real (1995b) pointed out that market waste is expected to be high in moisture content (> 60%) with a nitrogen content of around 2% and a C:N ratio of 20–40, making it highly acceptable for composting. However, if too high in moisture content this could become compacted and undergo anaerobic breakdown and become offensive. From a technical perspective, Lopez-Real (1995b) considered that the market wastes could be co-composted with sawdust waste.

Composting scale

The first stage in the determination of appropriate waste management strategies depends on determining the likely scale of operation, likely operators and potential waste collection possibilities. Once options have been refined at this level, the most appropriate technical methodology can be considered. As an example, the waste-use strategies considered by Harris and Smith (1997) in connection with the DFID Crop Protection project for peri-urban Kumasi (Anon., 1998) are summarized in Table 1.2.

Type of composting

Composting may be aerobic or anaerobic. Anaerobic systems tend to be associated with the production of methane, a contributor to the greenhouse effect.

Table 1.2. Strategies for the management of waste for soil amelioration and crop protection.

Strategy	Comments
1. Use of raw waste	● Does not include the required 'composting' aspect for crop protection ● Limited opportunity to manipulate quality ● Subject to many quality constraints (see above)
2. Urban home composting	● Often traditionally practised in an 'informal' way with back garden heaps or pits ● Mainly household waste/livestock wastes, some crop residues ● Limited capacity to deal with large amounts of urban waste ● Many urban producers do not have gardens to use the compost ● Resistance because of attraction of flies, rats and snakes ● Relies on raising awareness
3. Peri-urban backyard composting	● As (2) above ● Does not address the problem or potential of urban waste
4. On-farm composting	● Usually relevant to farm wastes from livestock and crop residues but may also include household waste ● Labour a major constraint ● Does not address the problem or potential of urban waste
5. On-farm composting with waste input from peri-urban community or urban areas	● Has worked in some areas where farmers receive wastes ● Offers possibility of selecting higher value wastes for co-composting ● Labour a major constraint, only possible with minimal labour requiring techniques ● Likely cultural constraints to handling certain waste types ● Transport a major problem
6. Peri-urban community composting	● Does not address the problem or potential of urban waste ● Very few villages have their refuse collected by the district assembly; therefore, waste is available ● Land is unlikely to be a constraint ● Rubbish dumps are currently usually maintained by the women in the village; may need some additional/voluntary labour ● Limited opportunity for commercial development
7. Peri-urban community composting with other urban peri-urban input	● As (6) above ● Offers possibility of selecting higher value wastes for co-composting, such as surplus chicken manure ● Possible to enhance composting process to enhance crop protection aspects ● Possible cultural constraints to handling certain waste types ● Transport a major problem

Continued

Table 1.2. *Continued*

Strategy	Comments
8. Urban community composting	● Requires effective community organization or NGO activity ● Difficulty in sustaining voluntary labour ● Limited commercial prospects ● Likely mismatch between producers of waste and users of compost ● Appropriate in areas that are inaccessible or where refuse collections are unreliable ● Offers possibility of selecting higher value wastes for co-composting: livestock, market, organic household, agro-industrial wastes ● Possible to enhance composting process to enhance crop protection aspects ● Waste separation at source may be possible in higher income areas ● May encounter resistance from municipal authorities who see waste management as their business ● May encounter difficulties in access to adequate land and water resources ● May experience difficulty in disposing of low value non-putrescibles in the waste
9. Private enterprise (small/medium scale)	● More likely to be on urban fringe than in outer peri-urban area ● Poorly understood waste streams ● Currently very poorly developed market for organic fertilizer ● Offers possibility of selecting higher value wastes for co-composting ● Possible to enhance composting process to enhance crop protection aspects ● Waste separation at source may be possible in higher income areas ● Requires significant investment even for low-tech options
10. Municipal large scale	● Land available and secure ● Assumes municipal collection service ● Close link, physically and administratively, between collection/delivery sites, composting and landfill ● Possible subsidy, direct or hidden from municipal authorities ● May generate revenue at least to offset costs ● Likely to have (or train) staff to a reasonable technical level and better able to handle more difficult wastes such as night-soil + sawdust ● Can achieve good sanitation of wastes ● Possible separation of major categories only, such as market wastes, for composting ● Large volume production ● Depends on maintaining level of technology ● Tends to become bureaucratic and inefficient

Production of biogas by microbial digestion is effectively anaerobic composting, albeit of a more or less liquid substrate. Generally, aerobic systems are favoured as they can be achieved using low technology, are easier to manage and reduce the waste to a stabilized form more quickly. Simple anaerobic decomposition methods can be employed by using pits or trenches that are covered with soil and left for long periods. This is sometimes more acceptable where night-soil and refuse are mixed.

Composting technology

It is beyond the scope of this chapter to review the technical options for composting but options for aerobic composting include open systems such as windrows and static aerated piles, in-vessel systems and even vermicomposting.

27. Are there processing constraints relating to land availability?

The availability of land sites for processing of waste can be a major constraint (Hardoy *et al.*, 1992). In Bangalore there were problems of finding an area of land with water for composting (Rosario, 1994). The high cost of land was also cited as one of the reasons why composting schemes in several Indian cities had closed (Jalan *et al.*, 1995).

28. Are there processing constraints relating to technology implementation?

The safe, acceptable and appropriate use of wastes in peri-urban agriculture is clearly enhanced when infrastructure and methodologies for required processing are in place. In general this represents a major constraint, since those countries and communities that perhaps have the greatest need of waste recycling for economic and agricultural reasons, often have the poorest provision of processing plants and equipment. The processing of organic wastes for soil amelioration is often attempted using medium- or large-scale technological approaches, although this is usually more to do with the economics and practicalities of handling large amounts of waste rather than a need for high technology processes per se. Organic waste can in fact be processed into a soil improver by very simple methods.

Plants in Morocco were built during 1962 to 1973 (Maung, 1982); by 1973 all the plants had broken down except one in Rabat which was processing 160 t of rubbish day⁻¹, a third of its intended capacity. Many of the reasons given for the failure of the projects were related to the technology employed and included incomplete facilities at the plant site, poor use of equipment, poor plant engineering, lack of skilled operating and maintenance personnel, and generally inadequate plant management.

29. Are there processing constraints relating to climate?

In dry climates where compost is prepared in windrows that are turned once they have passed the maximum temperature, turning can cause the compost to dry out and the compost has to be watered. Conversely in wet climates, as in Cameroon (Ngnikam *et al.*, 1993), composting may be the favoured option for waste disposal because burning the rubbish is not possible as it tends to be mainly organic with a high moisture content.

30. Are there processing constraints relating to supply/capacity?

Smaller plants may be attractive because they may be less susceptible to disruption caused by shortages of fuel or spare parts, or by strikes. However, there can be difficulties in choosing the sites if it is unclear how much waste can be collected from the district that each plant serves. A plant may subsequently turn out to be too small or too far away from the district it serves (Schweitzer, 1989).

31. Are there processing constraints relating to institutional support?

Many of the most successful waste management projects have relied heavily on support from local government or from NGOs or community groups. In many instances, as part of their responsibility for waste management, municipalities are prepared to subsidize the processing and use of organic wastes for agriculture. In Jakarta (Simpson, 1993), start-up grants, technical assistance, worker training and guaranteed purchase arrangements for the compost were made available and Jakarta city council provided collection and delivery of fresh rubbish and removal of non-compostable residues.

32. Are there processing constraints relating to regulation/control/acceptability?

There are likely to be planning restrictions on the siting and operation of waste processing plants. Home composting schemes often meet resistance because of attraction of flies, rats and snakes.

33. What is the best method of using the waste for soil improvement?

Generally, the material is applied either by incorporation into the soil during cultivation or to the growing crops as a mulch. The most appropriate application method should be considered on a case-by-case basis.

34. What is the availability and use of alternatives on farms?

There are suggestions that organic wastes are most readily used in agriculture where alternatives are not available or are too expensive (Owusu-Bennoah and Visker, 1994). Similar conclusions have been drawn by Lardinois and Van de Klundert (1994a,b). Farmers may be prepared to buy bulk compost in countries where the soils are desperately short of organic matter and where most alternatives are unavailable or impractical. Chemical fertilizers have a number of benefits. They are easy to transport, store and spread, have low costs per unit of fertilizer, crops react rapidly to them and they can guarantee high yields. However, they are also expensive and are often simply unavailable. In these circumstances organic waste materials may represent the only fertilizer option.

In contrast, there are many examples of positive preference for fertilizers derived from organic wastes. Farmers near Kano favour urban wastes as fertilizer since their effect once applied might last for 2 or 3 years, whereas two or three applications of artificial fertilizer might be required during the growing season. This is seen as a benefit because the reliability of all fertilizer supply is poor.

35. Which farming systems are most likely to use the waste and on which crops?

For reasons of availability and transport, urban organic wastes are used predominantly on the type of crops grown close to urban centres, especially vegetables (Siemonsma and Piluek, 1993). This does not preclude the use of wastes on agricultural field crops in peri-urban areas. For example, Anon. (1991) in Senegal reported the application of town refuse to farmland to increase the productivity of sorghum. Considering the Kumasi peri-urban area, Harris and Smith (1998) advanced the hypotheses in Table 1.3 for the potential for composted urban waste in different farming systems classified by Blake *et al.* (1997).

36. What are the farm/household economic considerations?

Where urban and peri-urban farming is a survival strategy, the levels of inputs are often very low. Few such farmers can purchase fertilizer, whether chemical or organic. However, the urban and peri-urban areas are also characterized by greater market opportunities and greater off-farm employment opportunities. Both of these stimulate entrepreneurial approaches and investment opportunities for crop and livestock production for urban markets.

Table 1.3. Hypotheses on the potential use of composted urban wastes in different farming systems.

System	Potential for use of composted urban wastes	Opportunities/constraints
Bush fallow mixed cropping	Very low	● Traditional bush fallow system for subsistence plus surplus ● Limited current use of inputs
Sole crop cereals	Low	● Bush fallow system but often more for cash income ● Limited fertilizer inputs, relatively large-scale farms ● Likely to encounter major logistical constraints ● Very impressive short-term soil fertility crop protection benefits would have to be demonstrated and very favourable cost–benefit relationships
Sole crop vegetables (rainy season)	Low/medium	● Sometimes opportunistic cultivation as part of bush fallow rotation ● Opportunities and constraints as for sole cereal crops ● Greater requirement for pest and disease control and higher value of crops may increase potential
Sole crop vegetables (irrigated)	Medium/high	● Especially where this forms an intensive use of land over several years
Specialized valley-bottom cropping	Medium/high	● Continuous cropping of cash crops close to urban markets and sources of compost ● Considerable potential for increasing yields ● Likely to be favourable cost–benefit relationship
Tree crops	Low/medium	● Perennial crops that can benefit from applications as mulch
Backyard farms	Medium	● Continuous cropping, mixture of perennial and annual crops ● Opportunity for long-term building of soil fertility ● Production may be mainly for home consumption with less concern for yield and less willingness to purchase/ transport compost ● Natural place for using products of home compost and small-scale community compost products

37. What is the likely demand for the final products?

A report from a study tour of composting initiatives in the Far East (Anon., 1979) found the lack of a rural market. Farmers in both Thailand and Japan showed little interest in urban compost even when the price was reduced to 20% of the cost of production. Progressive farmers preferred to use inorganics, conservative farmers locally available manure. Elsewhere, a market can be created only where the price is subsidized effectively or when other economic, social or environmental factors play a part. Proyecto Biomasa, an Austrian government supported initiative in Nicaragua, produces about 700 kg day⁻¹ of semi-dry compost. The compost is sold to growers of mangoes and melons and organic coffee producers. However, compost sales do not cover the costs of production (Foidl, Proyecto Biomasa, personal communication, 1996).

In Europe, where farmers are not prepared to pay a high price for compost but will use it, governments have a legal duty to dispose of wastes and may see compost making and use as a waste disposal strategy rather than an income generating one. However, private individuals and enterprises will not be interested in collecting, processing, and trading such low-value material, which will remain the responsibility of the city in which it is generated.

Despite the uneconomic production of composts from organic wastes in many places there are also documented cases of viable unsubsidized markets for composts. In Egypt, compost produced by the Zabaline (a group of Coptic Christians) is sold to farmers up to 150 km from Cairo (EQI, 1988). The situation in Egypt is unusual in that while soils lack humus, there is water available from the Nile and sophisticated urban markets are prepared to pay high prices for fruit and vegetables.

38. Are there constraints to use or considerations relating to knowledge/perceptions?

Among the reasons cited in a recent survey (Harris *et al.*, 1998) for not using organic fertilizers are lack of awareness that methods exist, lack of training, lack of detailed instructions, application methods and rates, and lack of proof of success. Maxwell and Zziwa (1992) also specifically asked farmers in Kampala if they made use of urban wastes but none did. Apart from an unwillingness to use the wastes, they believe that they had no value in agriculture.

Lack of technical advice was also one of the most significant constraints voiced by other farmers. Streiffeler (1987) reports that some cultivators in Kisangani, Zaire, observed that yields of cassava and banana were declining. The people realized that it was because they were not fertilizing their crops adequately but did not know that compost could substitute for expensive or unavailable chemical fertilizers.

Farmers may be unwilling to change to organic fertilizers because of the fear of failure or the risks involved. There are a variety of other reasons why

farmers choose not to use organic techniques, including composts, even when they are available. For example, because they are perceived as providing too long-term results, or are old-fashioned or ineffective. There is sometimes concern that composts introduce weed seeds, pests and diseases to the farm and the absence of these has to be guaranteed (Harris *et al.*, 1998).

39. Are there constraints to use or considerations relating to cultural aspects?

In many societies in sub-Saharan Africa contact with human faeces is considered defiling. Koranic edicts prohibiting contact with all human wastes are widely upheld in Islamic societies. The use of human excreta in agriculture and aquaculture is not condoned. While Islamic law is quite clear in regard to contact with human wastes, resource constraints, and religious, cultural and ideological variations lead to a variety of practices (Allison *et al.*, 1998).

Although there may be initial prejudices against the use of compost containing faeces, these may be overcome through education and practical demonstration. A recent study on the use of composting latrines in Tanzania showed that users' prior held beliefs had little bearing on the acceptability of the technology. There was no significant difference in willingness to use the compost between Muslims and Christians. It seemed the compost was sufficiently different from faeces not to be taboo. It has been suggested that cultural proscriptions on contact with excreta are more widely held among urban middle and upper classes than among the resource-poor, where attitudes are mixed.

40. Are there constraints to use or considerations relating to gender?

Gender balance in waste collection and processing varies with location and scale. Home and community composting may be almost exclusively a female role, whereas employment in the municipal waste processing chain may be exclusively male. Since the use of urban waste is predominantly in urban and peri-urban agriculture, the gender balance in urban waste use might be expected to reflect involvement in agriculture generally. Ratta (1993) reported that in Peru 80% of urban agriculturalists were female, with a figure of more than 50% for Kenya. In contrast, in Senegal, China and Brazil they were mainly male. It seems that the differences in the number of men and women involved in urban agriculture may depend on whether the agriculture is for subsistence, in which case women tend to be involved, or to generate cash when it becomes a more 'male' activity.

41. Are there constraints to use or considerations relating to tenure/land availability?

Farmers in urban and peri-urban areas often face the difficulty that they lack security of tenure. This means that they tend to grow annual crops (Maxwell

and Zziwa, 1992). The most significant constraints voiced by farmers are lack of access to land, capital, inputs, tools and technical advice. Farmers on the edge of expanding cities are less likely to invest in the use of long-term soil improvers such as urban waste if they are unsure how much longer they will be using the land, particularly when they do not have legal entitlement to the land they cultivate. Conversely, there is often an incentive, on rented land, to use high chemical inputs to guarantee immediate and economic return on land rents.

42. Are there constraints to use or considerations relating to institutional support?

The potential for use of composted urban wastes will be affected by the extent of their promotion through national or local government and NGOs. Use can be supported externally by international organizations, donor agencies and NGOs. In many instances, as part of their responsibility for waste management, municipalities are prepared to subsidize the processing and use of organic wastes for agriculture. In some instances governments contribute through supporting education campaigns. For example, McGarry (1976) reports increased use of night-soil in China in the 1950s because of government campaigns to encourage night-soil collection. The collection rate increased from 70% in 1952 to 90% in 1966 (Chao, 1970).

Generally, links between city governments and agriculturalists in and around cities are weak. There are a number of reasons for this. In the European model of city government adopted by many colonies at independence, agriculture has not traditionally been a concern of municipal authorities and urban agriculturalists tend to be neither a highly vocal nor an organized group, since they often exist as squatters, or agriculture may even be forbidden in urban areas (Maxwell and Zziwa, 1992).

Streiffeler (1987) mentions how the Nairobi government at one point ordered the destruction of spontaneous agriculture in the city. Cities with such attitudes to urban agriculture are unlikely to implement the appointment of agricultural extension officers and mechanisms for encouraging the use of urban waste by local farmers. One example of a city that actively encourages agriculture within its confines is Havana in Cuba. Because of the lack of agrochemicals the Cuban government is encouraging people to adopt organic cultivation methods. The government provides other forms of legislative support for urban agriculture; cooperatives have guaranteed use of the land for 10 years and are authorized to sell their produce at prices outside the controlled state sector.

Some policies may restrict the use of waste-derived soil ameliorants. Governments may have policies governing the sale and use of materials as fertilizers, sometimes developed to protect, promote, and subsidize appropriate chemical fertilizer use. In developed countries there are also environmental regulations, voluntary codes and designated sensitive areas for

regulating application rates, particularly with regard to nitrogen and heavy metal loading.

Conclusions

Most organic production occurs in rural areas, and consequently most organic wastes are found there including manure from livestock and residues from crops. Use of much of these wastes is integrated into the farming system. However, there is a vast traffic of organic materials into cities to feed and clothe the inhabitants and provide the raw materials for the industries that tend to be located there. Significant quantities of organic wastes are also produced by agricultural enterprises in and around the cities. As development occurs and urban populations increase, the type of waste generated is likely to change and the amount to increase. Productive use of these organic wastes is desirable to conserve resources and to protect the urban environment.

There have been many technology-based projects concerned with the use of municipal and/or agro-industrial wastes as soil ameliorants in agriculture. In many cases the technologies have been thoroughly studied and the main constraints associated with these technological projects seem to be a lack of resources rather than a lack of research information, and include lack of suitable land, finance, transport and maintenance of equipment. Such projects may generate a product for which there is an insufficient market or use, in some cases justifying this on the grounds of waste disposal alone. There are also a number of case studies of small-scale waste processing and use by individuals, cooperatives, communities, NGOs and private enterprises, where the end-products of processed waste are used in agriculture.

There have been far fewer studies starting from the basis of establishing the need for organic wastes in existing urban and peri-urban agricultural systems and investigating the potential to satisfy these needs within current resource constraints. There are a number of significant gaps in knowledge on the availability, value, processing, marketing, application rates, consistency of quality and efficacy of wastes at the farm level. The wide range of opportunities and constraints influencing the use of waste-stream products for soil amelioration should be thoroughly investigated before embarking on projects to develop this resource.

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Economic, Sociocultural and Environmental Considerations

2.1 The Economic Viability of Organic Waste Composting

R.G. NIEMEYER, H. LITTERSCHEID and S. SANDERS

GFA-Infrastruktur und Umweltschutz (GMBH), Bonn, Germany

This chapter concentrates on the essential elements of economic decision-making with respect to urban waste composting. The decision-maker should be able to identify suitable alternatives for both technical and economic services within a particular project. Finally, a tool is presented to gain a rapid overview over expected investment and operating costs.

Key words: economic viability, organic wastes, composting, economic evaluation, costs, decision-making

Introduction

Economic feasibility is of prime importance in ensuring sustainability of any project. However, a major problem of many compost projects is that the people in charge do not have the necessary information for an economic assessment or the information has not been processed adequately. Information is normally missing on aspects related to possible technical alternatives and corresponding costs of the individual stages involved in the use of organic waste.

If the production costs for compost and its selling price are not known, the contribution margin cannot be calculated, neither can a final decision on the type of waste treatment (labour intensive or machine intensive) be taken, at

least from the economic point of view. Furthermore, if the composition of costs is not known, the partial processes, which incur the most costs, cannot be identified and therefore it is not possible to save costs by initiating the relevant changes. Hence it is of prime importance for decision-makers that no aspects, which are important for the economic feasibility of the project, are overlooked.

Prerequisites

Before a decision is taken on the utilization of organic waste through composting, the most important prerequisites must be tested according to economic principles. As shown in Box 2.1.1, it is possible to differentiate between prerequisites, which are absolutely necessary and other aspects, which would facilitate the introduction of composting organic waste.

After examining the basic preconditions, the question of cost coverage should be looked at. The most important types of cost coverage for the use of organic waste as compost are summarized in Box 2.1.2.

Methodical Procedure for the Economic Evaluation of Composting

The use of organic waste in comparison to landfills is more sensible in ecological terms. However, waste use incurs higher costs and it is not immediately apparent whether these extra costs can be covered by the sale of compost and the cost savings on landfills. This question can be answered by a detailed investigation of the economic aspects of composting.

During the composting process services are rendered (collection, transport, processing of organic waste) and costs are incurred. These should be differentiated as follows:

- where (during which process) the costs are incurred (cost centre);
- which costs are incurred (type of costs);
- the level of costs incurred (possible alternatives for each cost centre).

The *overall process* that encompasses the use of organic waste can be divided into partial processes (collection, transport, transfer, etc.). Within a *partial process* further activities are carried out, which may be termed *sub-processes* (e.g. partial process of treatment containing the sub-processes of grinding, desiccation, storage). The various sub-processes can be regarded as cost centres from the economic point of view since they are points where costs are incurred. Various alternatives are available for the services required (e.g. grinding either manually or with a machine, e.g. shredder, chopper, etc.) for each of these sub-processes.

The choice of a particular alternative will result in certain fixed costs

Box 2.1.1. Economically important prerequisites for composting.**Vital prerequisites**

- Willingness of the local authority to improve waste treatment, and possibly to include state institutions, as well as the willingness and means to charge rates if required.
- Sufficient supply of organic waste and suitable composition for composting.
- Ensured sales of compost. This requires a high, guaranteed quality and a sales price for compost that does not exceed the ability and willingness to pay on the part of compost users.
- Availability, at good terms, of the necessary financial means for the initial investments.

Other important conditions

- The separation of organic waste when waste is produced or when it is collected. If waste is not separated, the costs for transport and later separation are too high to ensure a constant high quality of compost and economically acceptable use of compost.
- Increasing public awareness and advising waste producers on the importance of waste separation.
- The distance between waste producers and the composting plant as well as between the composting plant and the compost purchasers must be as short as possible to minimize transport costs as part of the overall costs.
- Evaluation of the waste disposal costs of the local authority to enable these to be compared with the costs of a private disposal scheme.
- Willingness of the state or the local authority to privatize waste management in order to use the potential for more economical management of waste composting, also acceptance of informal waste gatherers and their legalization and organization.
- The price for compost should not be higher for the end users (farmers, gardeners) than the price for comparable organic or mineral fertilizer (reference price). State subsidies for mineral fertilizers should not be higher than those for compost.
- Information for farmers on the use and benefits of compost to encourage them to become users instead of buying imported fertilizers.

(personnel costs, material costs, depreciation, etc.) and variable costs (operating funds), which can be categorized according to the type of cost. Selecting the right technical alternative will depend on the overall economic background to the project and the financial resources of the Project Executing Organization.

The choice of one alternative can also limit the number of possible alternatives for subsequent sub-processes (for example: if static windrows are selected for the maturation process, an aeration system is needed for ventilation).

Box 2.1.2. Components of cost coverage.**Economically important components of cost coverage for waste composting**

- **Sales of compost**

Compost results from the collection and treatment of organic waste. The sale of this marketable product must achieve cost coverage either in full or at least to a large extent. If earnings from the sale of compost cannot cover overall costs, the cost of collection and treatment must be offset by levying rates or other compensatory payments.

- **Levying charges on waste producers**

According to the producer principle, the amount charged should cover the cost of waste disposal (full cost-coverage). The collection of charges must have a legal foundation (a law which enables local authorities to levy rates or charges).

Even if there is a legal basis for charging rates, the local authority is often not in a position to collect them (no executive power). Moreover, many households are not prepared to pay for waste disposal if illegal waste disposal can be carried out on the nearest unused piece of land. For this reason it is important to provide information on the questions of hygiene and ecology in order to encourage residents' participation. The level of rates should be adjusted to local conditions. Rates can be linked to the amount of waste or can be the same for all waste producers. Rates should not exceed the willingness and ability to pay on the part of waste producers.

- **Compensatory payments by local authorities**

The introduction of composting means savings in landfill costs for organic waste. This justifies a payment for composting by the local authority, at least to the amount of costs saved. Furthermore the local authority could consider a subsidy with regard to the positive effects of composting as well as urban hygiene and ecology.

For the following economic evaluation various technical assumptions have been made in order to concentrate on the most important elements of cost accounting and subsequently evaluate the technical processes, which can be used for waste treatment and use.

Technical assumptions:

- *Separate evaluation of compostable organic waste.*
- *Separate collection* of organic and inorganic waste. The waste must be separated by the producer, otherwise the costs for transport and separation would be too high and the compost quality lowered in marketing terms.
- *Pick-up waste collection system.*
- No evaluation of alternative or direct possible *uses for organic waste without further treatment* (use as fodder, spreading directly on to agricultural land).

Where during the composting process are the costs incurred?

When using organic waste certain processes are carried out that can be categorized. The type of process and sequence are determined by the overall technical requirements for composting and are basically comparable. From the economic point of view these processes can be compared to cost centres. Each sub-process creates certain costs (relative to a unit of compost). Table 2.1.1 lists the main types of cost centre. Regarding the cost centres in Table 2.1.1 it should be noted that:

Table 2.1.1. Partial processes (Pp) and sub-processes (Sp) as cost centres.

Pp1	Household collection
Sp 1.1	Waste separation (source separation for household waste disposal)
Sp 1.2	Increasing public awareness
Pp2	Collection and transport
Sp 2.1	Collection (standardized containers for lifting system on truck)
Sp 2.2	Transport from producer (general collection vehicle)
Pp3	Transfer
Sp 3.1	Transport to transfer station (centralized composting)
Sp 3.2	Recording of waste volume at transfer station
Sp 3.3	Transfer process (transfer equipment)
Sp 3.4	Transport to composting plant
Pp4	Processing
Pp4.1	Delivery
Sp 4.1.1	Registration of amount of waste at composting plant
Sp 4.1.2	Separation of extraneous material
Sp 4.1.3	Processing of fractions
Pp4.2	Treatment
Sp 4.2.1	Grinding
Sp 4.2.2	Drying/moistening
Sp 4.2.3	Interim storage
Sp 4.2.4	Addition of bulking materials
Sp 4.2.5	Mixing
Sp 4.2.6	Stacking
Pp4.3	Maturation
Sp 4.3.1	Intensive maturation
Sp 4.3.2	Turning
Sp 4.3.3	Post-maturation
Sp 4.3.4	Ventilation
Pp4.4	Customizing
Sp 4.4.1	Screening
Sp 4.4.2	Screening with air classifier
Sp 4.4.3	Screening of resistant materials
Pp5	Marketing
Sp 5.1	Bagging
Sp 5.2	Storage
Sp 5.3	Sales
Sp 5.4	Transport to customer

- Partial processes themselves do not contain any activities.
- The partial processes 'transfer' and 'treatment' incur certain costs relative to the work site, i.e. costs for construction (e.g. sealing of the bottom of pits, fencing, restrooms for workers, administration buildings) which are required so that the subsequent sub-processes can be carried out. They are absolutely necessary, but cannot be assigned directly to a sub-process and are independent of the alternative chosen. A list of the work site costs is given in the calculation model.
- The partial process 'transfer' (Pp3) is not absolutely necessary. Its economic relevance depends on whether a central or decentralized composting system is chosen.
- The sub-processes indicate where (or when) costs occur during the overall process. The amount and composition of the costs depend on the alternatives selected. Basically a service can be provided in more than one way for each sub-process (e.g. manually using hand-held tools or else mechanized using a special machine).

Which types of costs are incurred?

For cost centres the question is: where are costs incurred during the composting process? For cost type the question is: which types of cost are incurred? Different types of cost can be identified for each sub-process, e.g. personnel and material costs. Table 2.1.2 gives a classification of the different types of cost for the composting process.

The level of individual types of cost can vary considerably from country to country. Classes 1 (personnel costs) and 4 (depreciation) are especially subject to wide variations. The ratio of certain types of cost to overall costs is of particular importance when deciding on the level of mechanization.

The alternatives available within a sub-process are often characterized by variations in the degree of mechanization which in turn is reflected in the types of cost. Alternatives with a low degree of mechanization – or a high level of manual labour – will incur mainly personnel costs. A high degree of mechanization with machines predominantly in use will mean that material and other non-personnel costs and also depreciation are the largest cost factors.

What are the costs of technical alternatives?

As the last element of economic assessment, technical alternatives must be tested for their cost relevance. The following aspects must be considered:

- The goal must be to minimize costs per unit of quantity of compost.
- The selection of certain technical alternatives will depend on the volume capacity of the composting plant (throughput in t of compost year⁻¹).

- The cost structure of a particular area of use must be considered. In developing countries personnel costs tend to be lower than in industrialized countries, given the same performance input, due to lower wage levels, whereas costs for depreciation of plants tend to be higher. The latter is due firstly to higher purchase costs and secondly to the shorter useful life of plants, as is often the case.

All processes for the use of organic waste, from waste collection to the marketing of the compost, can be carried out using either advanced technical methods or with basic manual processes. The production factor 'capital' can be substituted almost completely by the production factor 'labour' and vice versa. Furthermore, the acceptable price for compost will be relatively low and therefore transport and treatment costs will be deciding factors.

The following recommendations should be followed if possible:

- Transport costs should be minimized through decentralized composting plants or transfer stations. The locations should be chosen so that the distance to the procurement market (location of waste producers) and to the sales market (compost purchasers) is as short as possible. The distance to

Table 2.1.2. Types of cost for waste use with composting.

Class 1	Personnel costs
1.1	Wages and salaries (excluding transport, maintenance and administration)
Class 2	Material and other non-personnel costs
2.1	Electricity
2.2	Water
2.3	Fuel (without transport costs)
2.4	Heating oil
Class 3	Outside services
3.1	Outside services
Class 4	Depreciation
4.1	Buildings
4.2	Machinery
Class 5	Cost of financing
5.1	Cost of financing
Class 6	Cost of waste disposal
6.1	Cost of waste disposal
Class 7	Semi-variable costs
7.1	Maintenance costs
7.2	Transport costs
7.3	Administrative costs

Note: Similar cost types are classed together. Sub-divisions are made in accordance with general accounting principles, but have been adapted here to the specific requirements of the composting process. The semi-variable costs in class 7 have been selected because it is very likely that the relevant data are available or can be ascertained. However, double recording in other classes should be avoided. Costs for the purchase of land are not considered here since land does not depreciate in value as a result of being used. The cost of land is included in the calculations for the cost of investment.

the procurement market should be given priority since organic waste has a greater volume than compost (higher transport costs).

- The treatment technology should be chosen to include the production factors, which incur relatively low costs.

Since it is possible to substitute the production factors 'labour' and 'capital' with the corresponding types of cost 'personnel costs' and 'depreciation/cost of financing', the ratio of the level of these types of costs plays an important role in establishing the optimum degree of mechanization for the composting process.

The economic evaluation of alternatives has shown predominantly that personnel costs are incurred for low levels of mechanization, whereas for the more advanced technical methods the question of depreciation and cost of financing plays a vital role. Depending on the cost ratios of the country in question, methods should be chosen that incur the lower types of cost. For example, if wage levels are low, but purchase costs high, then a labour intensive, low level technical method of composting should be selected.

In this case labour intensive methods of composting will have additional beneficial effects: unemployment will drop and the income level of the poorer section of the population will improve.

Special Aspects of the Economic Evaluation

Capacity of the composting plant

The choice between technical alternatives depends largely on the expected or planned capacity of compost production (t year^{-1}). Manual processes are more suited to small throughput amounts, whereas a high throughput will require a higher level of mechanization. The reason is that a certain volume (in the form of marketable compost) is needed to cover the high cost of depreciation caused by the purchase of machinery. The same is true of material and other non-personnel costs given a high level of mechanization. These costs will also include energy costs and operating funds. Every plant has a specific breakeven point in terms of throughput where it becomes worthwhile to set up a plant, depending on the purchase costs of the organic waste and its selling price.

Centralized or decentralized composting

Since the money value of organic waste per unit of quantity is very low, transport costs are a limiting factor in economic terms. In order to minimize these costs, two alternatives are possible: a centralized composting plant with several transfer stations or several decentralized composting plants without transfer stations. It should be noted that a lower level of mechanization is more suitable for decentralized composting plants.

Landfill costs

Savings on landfill costs through the use of organic waste must also be included in an economic evaluation. A differentiation should be made depending on whether landfill costs for organic waste are already being paid or not. If costs are not being paid, the local authority will not achieve any further savings through composting, i.e. the landfill costs saved will have no effect on the operating result and should not be included in the cost calculation. Nevertheless, there is an ecological benefit to composting, although the economic effect will only be apparent when viewed from a broader perspective.

Technical service life as a basis for depreciation

With regard to depreciation, it should be noted that the level of depreciation is directly dependent on the estimated service life in economic terms. This in turn should be based on the technical service life, which can vary widely according to country or specific conditions. For example, if the service life of a machine is unusually short because of climatic conditions or lack of maintenance, the annual depreciation costs will rise and with them the costs of process alternatives where the machine would be used. A shorter technical service life could mean that a highly mechanized procedure, which originally was considered preferable, has to be regarded as impractical from the economic point of view. The chosen length of depreciation must therefore be adapted to actual conditions.

Maturation process: plants with high or low degree of mechanization

The sub-processes described in partial process 4 (processing) and their alternatives fall into two main categories:

- Plants with a low level of mechanization normally combined with labour intensive, but not capital-intensive alternatives. Static or dynamic windrow methods are recommended for the main maturation period.
- Plants with a high level of mechanization, normally combined with capital intensive, but not labour intensive, alternatives. Partially or fully encapsulated methods are recommended for the main maturation phase.

The decision on the level of mechanization for the maturation phase depends on the following factors:

- Planned capacity of the plant. Highly mechanized plants are only economically viable if they are in full use. Due to the short maturation phase, a relatively high throughput rate is required to operate the plant at full capacity.
- Available space and price of land. Plants with a low level of mechanization require more land than highly mechanized plants.

- Available funds for the investment. Highly mechanized plants required a level of investment many times higher per tonne of compost than plants with a low level of mechanization. It should also be noted that foreign currency might be required to buy technical equipment on the world market.
- Level of personnel costs, particularly for simpler tasks. Since plants with a low level of mechanization are very labour intensive, they will have a comparative advantage if wage levels are low.
- Level of funding to cover running costs, particularly material and other non-personnel costs, since highly mechanized plants require more energy and operating funds. Higher maintenance costs must also be considered.
- Existence of legal regulations governing emission values. Highly mechanized plants guarantee lower emission rates than plants with a low level of mechanization.

Calculation Model for Overall Costs

Decisions on the design and capacity of the utilization process or the composting plant must be based on clear cost calculations which preferably should be carried out using a calculation model developed specially for this purpose. A model is particularly useful for testing methods again and again until an acceptable solution is found. The model may have to be adapted for a specific scenario, but values and estimates should always undergo rigorous testing.

The model presented by GTZ/GFA (1999a,b) covers both investment costs and overall costs per year. These are divided into proportional site costs, fixed and variable operating costs. The model is designed for:

- Calculation of investment costs to ascertain the required level of financing.
- Calculation of overall costs to ascertain the costs per unit quantity of compost which in turn provides the basis for a simple calculation of the contribution margin. The relations between the different elements of the calculation are shown in Fig. 2.1.1.

After carrying out the calculation certain indicators will be available on investment costs and the contribution margin.

Investment costs

Investment costs show what funds are necessary to fund investments for construction and machinery required for the composting process. The costs are time-related and are composed mainly of construction costs for buildings etc. and the purchase price for machinery.

Investment costs show whether the financial resources chosen for the investments are sufficient. Financing may be provided from state or local authority funds that do not have to be repaid. A differentiation may be made between a

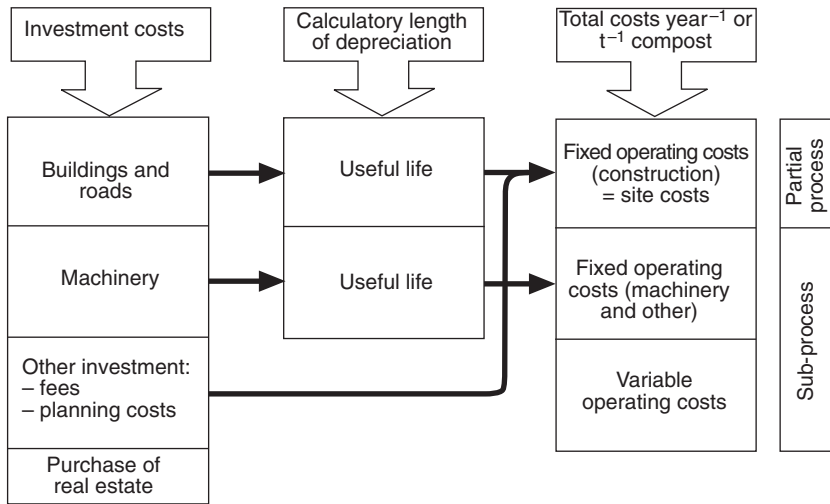


Fig. 2.1.1. Cost calculation basis for a composting plant.

single payment to cover investment costs and a running annual payment to cover operating costs. A further form of financing is via loans, where not only the actual investment amount must be paid back in yearly instalments, but interest costs are also incurred. If the required funding is calculated in excess of available funds, the decision-maker can choose between the following alternatives:

- Composting will not be carried out.
- Additional funding must be made available.
- Additional loans must be taken out.
- Alternatives must be selected with lower financing costs/depreciation and hence lower investment costs. In this case the cost calculation must be carried out again (iterative calculation process).

Contribution margin

The contribution margin shows whether a profit or loss can be expected from composting and how high, expressed in units of currency, the profit or loss will be per year or per tonne of compost. The contribution margin is calculated by comparing overall costs with overall earnings. Overall earnings are the expected earnings from sales and possible fees to be paid by the producers of waste and landfill savings (if landfill costs are already being paid), as well as additional funding. The contribution margin is the central indicator for ascertaining the *economic sustainability* of a project. If the contribution margin is positive, the project can be executed as planned – at least from the economic point of view. If the contribution margin is negative, the decision-makers can choose between the following alternatives:

- Composting will not be introduced.
- Additional funding can be made available.
- The fee to be paid by the producers of waste is raised. This is only possible within certain limits, which are determined by the willingness and ability to pay on behalf of the waste producers.
- The sales price for compost is raised. However, since there is a danger that less can be sold, the price elasticity of demand should always be ascertained.
- Alternatives are chosen which incur lower costs per year than the original choice. By varying the technical alternatives in different calculations overall costs can be minimized. Which combination of alternatives incurs the lowest level of overall costs depends on the level of costs in the country concerned.

The models should be modified according to each individual case. For example, costs for alternatives, which are not available for technical reasons, do not have to be calculated. Nor does it make sense if certain alternatives are excluded for economic reasons without having calculated their exact costs.

Interpretation of Indicators

The calculated indicators can only be a rough guide, since many are based on estimates. If only a few of the estimated basic data change, this will have a direct influence on the indicators themselves. This means that even if the indicators appear to show that composting can be financed and is also economically feasible, certain risks remain. This is because statements have to be made during the planning stage on later economic conditions.

Both the capacity of the plant and the yearly sales volume must be estimated, as must the target sales price and the waste collection charge. These estimates should be based as far as possible on representative data, and if necessary on empirical investigations, particularly with regard to the willingness to pay fees and the elasticity of demand.

The investment costs will be offset during the economic life of the plant by earnings (return of investment). It cannot be stated definitely at the planning stage when the first earnings can be achieved from the sale of compost. Delays may occur at the beginning of the operational stage, which will postpone earnings. Therefore a certain financial reserve is to be recommended. For example, the contribution margin should be high enough so that even if certain fundamental conditions change, it still remains positive and hence economic sustainability is ensured.

The present calculation does not make any statement of whether composting should be carried out by a private company or by a public institution. In either case the calculations and formulae contained in GTZ/GFA (1999b) are equally relevant. Whereas cost calculations are carried out for private companies beforehand, this is not always true for public institutions which can lead to grave mistakes when taking decisions.

The flow diagram of the calculation process shown in Fig. 2.1.2 shows that indicators can only be ascertained over several stages. For example, to estimate the investment costs, it must be clear which combination of alternatives has been selected. The diagram also shows clearly that if investment

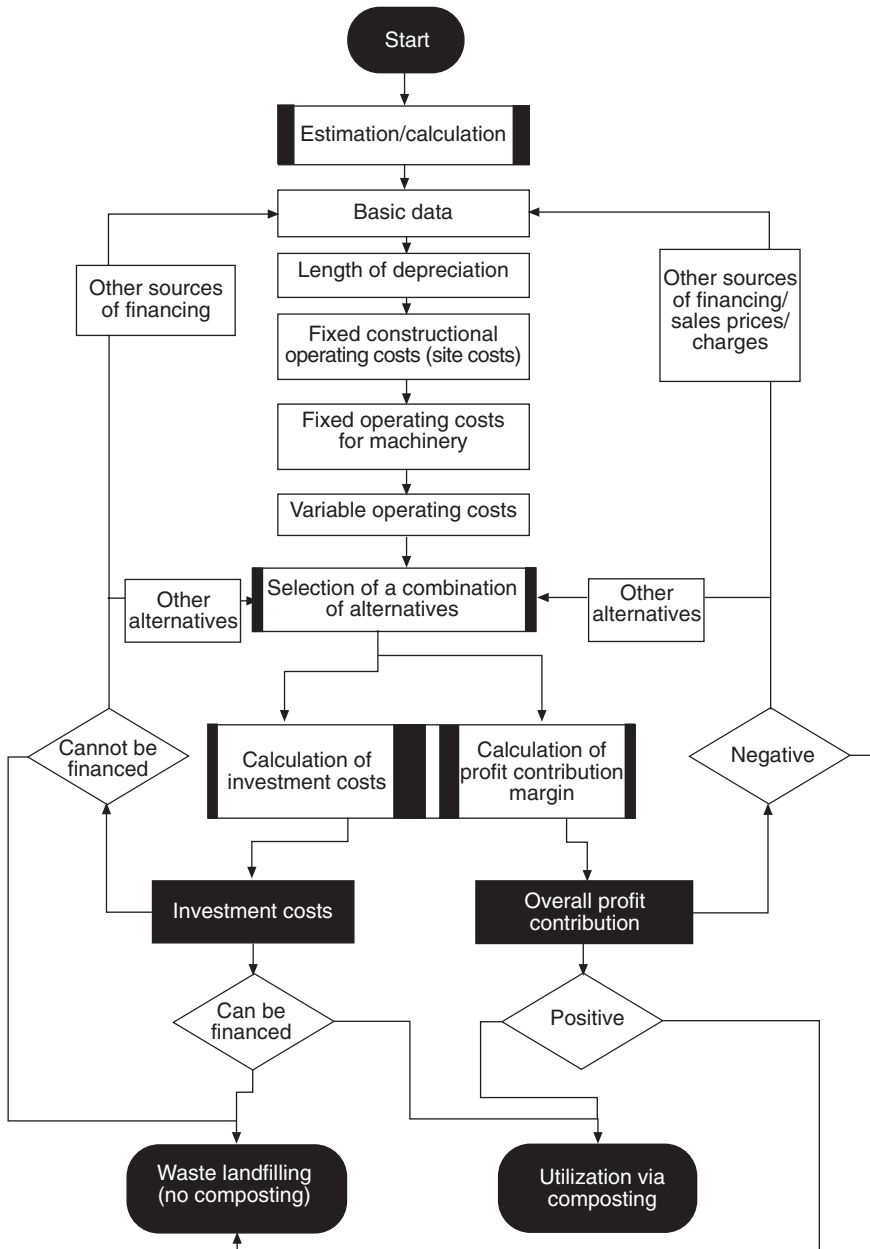


Fig. 2.1.2. Flow diagram for the calculation process.

costs are too high or the contribution margin is negative the calculation must be carried out again and certain parameters changed. It is also shown clearly that *both* indicators must be acceptable. Even if a high contribution margin is achieved, composting can only be recommended if the necessary investments (e.g. outside capital) can also be financed.

The 'Decision Maker's Guide to Compost Production'

A software tool called 'Decision Maker's Guide to Compost Production' has been developed by Deutsche Gesellschaft für Technische Zusammenarbeit/GFA-Umwelt (GTZ/GFA, 1999b) on the basis of this model. The program can be used without knowledge of the model since it contains a direct interactive user menu. In addition, a voluminous handbook (GTZ/GFA, 1999a) is available.

The tool gives planners and decision makers an easy-to-use way of choosing the most cost-effective alternative from the commonly available technical options for administration, collection, treatment and composting. The program, which can be used without specific computer knowledge using a normal Pentium®-PC with MS Windows 95/98 and MS Excel 97, leads directly to practical conclusions. The program language is English. Costs can be calculated in the currency of the country concerned. The program fits on a normal 3.5" floppy disk, can be downloaded from the GTZ homepage (www.gtz.de) or ordered at GTZ or GFA (www.postmaster@GFA-Umwelt.de).

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2.2 Assessing Farmers' Perceptions of Organic Wastes as Nutrient Sources

P. DRECHSEL¹, C. QUANSAH² and S. ASANTE-MENSAH³

¹IWMI (formerly of IBSRAM), Ghana Subregional Office for West Africa, Kumasi, Ghana; ²Department of Crop Science; ³Department of Agricultural Economics and Farm Management, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Are farmers' concerns towards the use of compost, night-soil or poultry manure more economic than cultural or vice versa? What are farmers' initial impressions of new nutrient sources? How much would they pay for them? Did farmers' attitudes change during on-farm trials? This chapter presents procedures and methods used to assess farmers' perceptions of compost and poultry manure as sources of plant nutrients in peri-urban Kumasi, Ghana.

Key words: West Africa, Ghana, farmers' attitudes, organic wastes, nutrients, poultry manure, composts

Introduction

Over the last few years, the Faculty of Agriculture of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, participated in two projects with focus on peri-urban agriculture. Both projects, the German Federal Ministry for Economic Cooperation and Development funded IBSRAM project and the Department for International Development funded Natural Resources Institute (NRI) project had components on organic waste recycling and both used tools for participatory innovation assessment to estimate the adoption potential of recycled nutrient sources. This was partly done in the framework of pre-project participatory rural appraisals (PRA) and partly as a monitoring instrument to receive farmers' feedback on technologies already being tested. In this chapter, some of the tools used in these two studies are presented as a possible guide for assessing farmers' perceptions of recycled organic waste as fertilizer.

As part of the NRI project, a PRA study was undertaken to investigate, among other things, farmers' perceptions of the use of urban compost and other inputs to identify potential socio-economic constraints in their use. The study was carried out in four villages within 20 km of Kumasi (Warburton and Sarfo-Mensah, 1998). In this case, most farmers had not used compost before, and their initial perceptions were recorded.

As part of the IBSRAM-supported on-farm trials in different communities of the Nkawie District of peri-urban Kumasi, participatory monitoring and evaluation (PME) tools were used to analyse farmers' perceptions of poultry manure, a major agro-industrial by-product around Kumasi, in a maize–cassava system (Quansah *et al.*, 1998a, b). Here, farmers had experimented with the manure for some time and their experiences were analysed with respect to the possible adoption of the technologies introduced.

This chapter focuses on the PRA/PME methodology and the interview guidelines (criteria/subjects) used for the discussions with the farmers. Some complementary tools are added from the general literature. Reference results are used mainly for illustration or to emphasize salient points worthy of consideration in related discussions or exercises.

The examples are derived from meetings arranged in different villages. Often, the participants were divided into men's and women's groups. The researcher teams that conducted the studies were multi-disciplinary (agronomy, rural sociology, extension, socio-economics, soil science).

Initial Perceptions

The basic idea of an innovation assessment is its comparison with known alternatives. A basic strategy for related discussions is to visualize the subject/alternatives as far as possible.

In the NRI study, vegetable farmers were asked to compare the characteristics of five types of inputs that were displayed and handed out:

- urban compost produced in Accra (= innovation);
- NPK;
- poultry manure;
- cow dung; and
- black soil (humus-rich soil taken from a local refuse dump).

To structure the discussion, a 'matrix ranking' exercise was carried out (Warburton and Sarfo-Mensah, 1998). This was done by drawing up a table with the different nutrient sources on one axis and crucial 'fertilizer' parameter/characteristics identified by the farmers on the other axis (Table 2.2.1).

The degree of how good the different nutrient sources match the characteristics was ranked using beans as counters (e.g. 5 = very good, 4 = good, etc.). Parameters/characteristics of importance for the participants were, among others, 'availability', 'price', 'fertilizer value', 'dirty nature', 'spreading weeds', 'no short-term effects' and 'bulky/difficult to transport'.

Table 2.2.1. Matrix ranking (example without scores); modified.

Nutrient source	Accra compost	Poultry manure	Cattle manure	Black soil	NPK
Expected to be good for crop growth					
Good for crop taste					
Easy to handle/apply					
Low price					
Supporting weeds					
Easy to transport					
Does not smell					
Availability					
Long-term effects, etc.					
Total scores					

A corresponding interview guide for the exercise is given in Box 2.2.1 (Warburton and Sarfo-Mensah, 1998; modified).

Box 2.2.1. Perceptions of compost and other fertilizers (interview guide).

To show:

Display available types of compost/fertilizer (farmers describe the composition of each type, assisted by researchers):

Accra compost, poultry manure, black soil, NPK, cattle manure, mulch, etc.

To ask:

Who uses these inputs already? Which type? How many farmers? What for?

To discuss:

Farmers discuss pros and cons of each type (own experiences or heard/expected):

- What are the attributes of a good compost/fertilizer?
- Type of crop/soil/problem best suited for.
- Effects of each compost (also bad effects).
- Expected cost and labour implications: transport, availability, soil incorporation.

Initial consumer price estimation:

In terms of an alternative fertilizer with a known price, i.e. to discuss how much urban compost would farmers exchange for, for example, NPK or poultry manure and to determine farmers' willingness-to-pay for soil improvement with compost.

Matrix ranking exercise

Make a chart showing the inputs and attributes (identified by farmers) and rank these (men and women separately). 5 = best/most important, 0 = worst/least important.

Analyse relative *preferences*: Which input is preferred overall and by gender? The final ranking of the different options or innovations to be initiated is shown in the last row.

Issues to be Addressed in the Discussions

Cost and benefits

- Benefits – direct, e.g. higher yields; indirect, e.g. by reducing other inputs, such as inorganic fertilizer and/or pesticides.
- Costs – actual compost costs (plant door price/retailer price), the packaging and transport to the field or nearest road, and the costs of labour to transport and incorporate the compost.
- If transport is a deciding factor, then the compost producing facilities may have to consider ways of producing a more concentrated and less bulky product, or smaller units, e.g. for head loads, or another location, closer to the farmer. The group may try to analyse farmers' willingness-to-pay (WTP) for the product.

Farmers' WTP

This analysis involves direct questioning of farmers to determine their willingness to pay for the recycled waste product, i.e. compost in our case. A number of different methods can be used to construct a hypothetical market situation and to collect data, although most rely on questionnaire-based surveys. The hypothetical market situation is set by describing a realistic scenario of change of a more or less intangible item, in our case improved soil conditions and yields. Farmers should be given information setting out the issues, especially the description of changes through the use of compost (if possible quantity/quality), the amounts of compost necessary to achieve these changes, the workload involved etc., i.e. the advantages and disadvantages. Without field trials it will be difficult to give information on a possible yield impact. Depending on the soil type the benefit might be related to improved physical soil conditions and/or nutrient supply. Also the time scale should be considered: composts from city waste might not release many nutrients in the first season, but compost with a high night-soil component would release nutrients earlier. Thus it will be also important to record if annual or perennial crops are grown. The farmer should then be asked how much he/she is willing to pay for this improvement of the soil. Alternatively, the farmer can be asked if he/she would pay, e.g. a certain amount, 'x'. If the farmer agrees, the amount can be increased in the next question, and vice versa if the farmer disagrees. The bidding game should come up with the maximum price that a respondent would be prepared to pay for better soil conditions. This survey can be conducted through face-to-face interviews with a representative number of farmers, recording among other things their gender, level of (on-/off-farm) income, soil type, target crops and their familiarity with the good (compost) in question, for example, by analysing their initial KASA values (see 'Monitoring of Perception Changes'). These explanatory variables can be used in a multivariate probit model, which comparable to the regression analysis, can be used to

analyse the effects of several independent variables on farmers's WTP (cf. Asenso-Okyere *et al.*, 1997; Nunan *et al.*, 2000). If the monetary figures mentioned by the farmer appear too high, it might be useful to ask him/her if he/she would spend less, the same or more for the new product than for a product (e.g. cow manure) he/she knows. In any case, it is recommended that the WTP analysis will be accompanied by an 'ability-to-pay' analysis.

Cultural taboos

Cultural taboos over handling night-soil and other waste products have been suggested as reasons why such composts might not be acceptable to farmers. In the case of the NRI study there was no indication that farmers would refuse to use compost for that reason alone. Farmers were reluctant to use products that are obviously dirty and unpleasant to handle such as black soil with untreated waste or wet poultry or cow manure that are malodorous. Farmers already grow plantain on waste dumps that contain night-soil. As long as the compost is treated so that it is odourless and easy to use, it is likely that other criteria such as the perceived effectiveness and costs of use will be the deciding factors for adopting this type of compost.

Perceived effectiveness

In situations where no farmer had made or used composts before, the perceptions about the Accra compost were based on what farmers thought of the sample shown to them. In the NRI example farmers thought that it looked mostly like black soil, and therefore tended to assess its effectiveness on crops in a similar way. All thought it would be less effective than NPK, especially on short duration crops such as vegetables. However, they may rate it more highly on starchy staples and perennial crops or on poor rather than rich soils.

Existence of other constraints on yield

If there are other major constraints to yield, however effective the urban compost might be, the yields will remain low. Examples might be problems such as lack of water, seed-borne viruses and poor quality seed. In these cases the farmers may not perceive much advantage in using compost.

Slow effectiveness and insecurity of tenure

Composts and manures act slower than NPK, and are thus more suitable for long duration and perennial crops. On the other hand, peri-urban vegetable farmers often face insecure land tenure. As a result, they are more concerned about

short-term effects than long-term improvements as they may only have rented the land for one season, or think that their land may soon be used for other purposes. Unfortunately this may tend to make farmers discount the longer term benefits of improving soil structure or other improvements due to the use of composts.

In the event of composts being uneconomical for vegetable growers with short-term access to land, then there may be other types of farming where urban composts can be used, for example, backyard farming or for perennial tree crops.

Availability and convenience

In all of the studies carried out, farmers stressed the importance of availability and convenience. The product must be odourless and easy to handle, and also available in small amounts so that it is affordable and easy to transport. Farmers' preferences for a clean, packaged product needs to be borne in mind when considering local production of compost.

Information needs

The discussions revealed that farmers need more information on new products, such as urban composts, for a more definite valuation. On-farm trials seem to be necessary to see the effects on crop yields for themselves. Once there is more information on yield differences per amount of compost used, partial farm budgets including the transport costs could provide some estimates of the price of the compost required to make it attractive to farmers.

Follow-up Evaluation

In the IBSRAM trials the innovation under study was poultry manure (PM) introduced into a cassava–maize system and compared in on-farm trials with PM plus mineral fertilizer (NPK) and no external input. The following methods were used to elicit information from the farmers:

1. Group meetings and discussions.
2. Farm visits to evaluate project trials by participating and non-participating farmers.
3. Single interviews with the aid of an interview guide (Box 2.2.2) covering the following areas (open-ended questions):
 - farmers' awareness of the existence of the trial;
 - sources of information on the trial (diffusion pathway of the technology);
 - attempts at diffusing information on the trial;
 - farmers' indigenous knowledge on poultry manure;
 - specific knowledge gained from the trial after the farm visits;
 - farmers' assessment of attributes of the innovation (relative advantage, compatibility, complexity, trialability, observability);

- perceptions of difficulties/problems associated with adoption of the technology;
- farmers' interest to adopt poultry manure in the coming planting seasons.

Box 2.2.2. Interview guide (PME). (Non-participating farmers – criteria 1, 2, 4, 6, 7; participating farmers – criteria 2–10.)

Criteria:

1. Awareness of the trial and source of information

Low awareness among non-participating farmers can be attributed to the failure of the project to organize, e.g. open-field days or to collaborate with the extension service.

The diffusion pathways of innovation can be extension, friends, project activities, field observations, etc.

2. Knowledge of the practice

The extent of indigenous knowledge on use of poultry manure before trial.

Visit to a trial/experimental site.

3. Specific knowledge gained from the trial of use of poultry manure

(List, itemize, e.g. state of decomposition, quantity to apply, method of application, time of application, effect on growth, effect on yield, etc.).

4. Farmers' assessment of benefits of poultry manure (list).

5. Matrix ranking analogous to the example shown above (comparison with alternative nutrient sources) but now with experienced characteristics, not expected characteristics.

6. Farmers interest in using poultry manure on their farms

No. Interested ...

No. Not interested ...

7. Desire to try poultry manure in the coming season

No. Willing to try ...

No. Not willing ...

8. Assessment of attributes of the innovation

The five main characteristics of innovations are: relative advantage, compatibility, complexity, trialability and observability. These parameters allow an assessment of how farmers perceive the innovation (trials).

Relative advantage e.g. low costs, yield increase

Complexity of practice

Complex ...

Simple ...

Compatibility with previous and current practices

High ...

Low ...

Trialability – that the technology is acceptable for small scale trials

High ...

Low ...

Observability – that the results of the effect of PM on crop growth and yield were clearly observable and convincing.

9. Perception of difficulties in use of innovation, e.g. in view of

Acquisition, collection, labour, finances, application, health hazards, availability, etc.

10. Identification of crucial indications for technology adoption/sustainability

Based on farmers' statements such as availability, low costs, ease of application, yield impact, support through local leaders, etc.

Group meetings

Group meetings were organized as a prelude to the farm visit and the unstructured interviews. The group meetings were held on taboo/communal workdays after permission had been earlier sought from the local community leaders (either the chief or the assemblyman). The taboo/communal workdays were days on which most people were available. After introduction of the researchers through their team leader, an overview of the on-farm research project was presented. The importance of farmers evaluating the effects of the different treatments was explained. To visualize the impact of the innovation ('seeing is believing'), a visit to the experimental sites was arranged.

Farmers' visit to experimental site

Evaluation by non-participating and participating farmers

To avoid influencing farmers' evaluation of the effects of the three treatments imposed on the crops, the plots were marked out simply and labelled as plots 1, 2 and 3. Farmers were not told what treatments had been applied. The participants were asked to make careful observations of the three plots and to note whether there were any differences between them.

Participants commented on the three plots. All observations were recorded. Participants' explanations as to the reasons for the differences observed were also recorded. Each farm visit took about 2 h and sufficient time was given for as many participants who were willing to make comments to do so.

After recording the observations of the non-participating farmers, the participating farmer in charge of the experiment was asked to present the treatments imposed on each plot, his observations of the effect of the treatment on the vegetative growth phase as well as the yield of the two crops – maize and cassava. Other observations on the soil, weed growth, etc. were also presented. Conclusions were drawn jointly with the non-participating farmers.

Single interviews and focus group discussions

These were conducted after the visit to the experimental site. The purpose was to capture the impact the experiment had made on the participants and also other information with respect to the adoption of PM for farming in the locality.

To ensure that the exercise was participatory, the study emphasized the use of open-ended questions that followed only rough guidelines (Box 2.2.2). The Akan language was used throughout (and by all participating scientists). This approach facilitated free self-expression by the farmers.

All stages of the exercise were recorded on videotape. This enhanced individual participation since most of the farmers wanted to see themselves on television or on the play back. The non-disclosure of the treatments imposed, and allowing participants to assess and comment on each plot stimulated participation in the discussions. It is probable that participation would not have been to the extent observed if participants had been informed about the treatments applied.

Monitoring of Perception Changes

In evaluating the impact and/or acceptance of innovations, there are several human characteristics such as knowledge and attitudes, which are not easy to assess. A method used to monitor related perception changes is the KASA analysis (cf. FAO, 1990), which was applied in the IBSRAM trials (Asante-Mensah *et al.*, 1998). KASA means the analysis of changes in *k*nowledge, *a*ttitudes, *s*kills, and *a*spirations with respect to certain activities or innovations (Box 2.2.3). The KASA analysis should therefore be applied as part of the initial perception analysis *and* at a later stage after farmers had have time to experience the innovation. The comparison of both results will show if and what kind of KASA changes have taken place during the period. Alternatively, farmers may be asked retrospectively about what they knew, thought, and expected at the start of an experiment and what they think now.

KASA changes were analysed during PME exercises to evaluate the introduction of PM for non-vegetable crops. In general, the analysis comprises a ranking/scoring exercise and related interviews. In view of, for example, knowledge changes, different subjects have to be identified together with the farmer, such as:

Box 2.2.3. KASA analysis.

When a farmer is exposed to an innovation, e.g. urban compost, he/she undergoes changes in *knowledge* of the innovation – he/she learns more about it. Also *attitudes* towards the innovation, if negative, may change to positive as a result of changes in his/her knowledge of the innovation. Next, the farmer may be motivated to try his/her hand at the innovation – to learn how to do it practically. Thus changes in *skills* on the innovation also occur. Finally, *aspirations* (what the farmer hopes for, or aims at achieving) also change because of changes in K, A and S. The farmer may therefore set higher goals (e.g. he/she may plan to obtain more bags of maize). Thus changes in KASA may lead him/her on to adoption if all other factors, especially economic viability, are favourable.

Table 2.2.2. Major KASA changes with respect to the introduction of PM as a new nutrient source in maize/cassava farming (IBSRAM/KNUST trials).

	Before introduction (1994/95)	After introduction (1997/98)
Knowledge	1. Little or no knowledge of the usefulness of PM. 2. Little or no knowledge of the effect of PM on crops. 3. Little or no knowledge of PM in sustaining crops during drought. 4. Little or no knowledge of method of application. 5. Little or no knowledge of state of decomposition required before application.	1. Much knowledge on use of PM in cultivation of many crops (maize, cassava, etc.). 2. Knows the effects on growth of leaves, stems, and yield. 3. PM conserves soil moisture to save crops, and produces appreciable yields during drought. 4. PM can be broadcast or applied as spot or ring application. 5. PM to be well decomposed before applying.
Attitudes	Negative attitude ● PM has a fishy smell. ● Thought acquisition was difficult. ● Thought it was difficult to use. ● Thought it was for vegetables only.	Positive ● PM smells, but the odour can be reduced with better/longer storage. The benefits are more important than the smell. ● Easy to acquire. ● Now knows PM is easy to use. ● Now knows PM can be applied on many crops.
Skills	● Could not determine the proper state of decomposition to apply. ● Knew only one method of application.	● Knows state of decomposition practically now. ● Can apply now in different ways.
Aspirations	● Thought I could not get any high yields.	● Expects higher yields when PM is used. ● To reduce hectareage since more bags of maize can be obtained from a small area if PM is applied. ● Will increase hectareage to get even greater yields and income since PM is available. ● To store more manure now for use later.

- the number of crops with which PM can be used;
- the effect of PM on crops;
- the effect of PM during drought;
- how to apply PM;
- when to apply PM; and
- the effect of PM on diseases.

At the start of the project, farmers could select per subject between different knowledge levels from nil to high (or ranks 0–4). If the same exercise is repeated after some seasons of farmers testing the innovation, then the two results have to be compared with regard to changes (positive or negative). There might be major differences in ranking certain knowledge subjects, skills or attitudes while others remain the same and may require further information or training. The differences between the ranks given at different times may allow a proxy quantification of larger and smaller changes. The exercise will be supplemented by interviews. Results from such interviews carried out in the framework of the poultry manure study are summarized in Table 2.2.2.

Conclusions

The methods and procedures described in this chapter for PRA and PME studies are effective tools for assessing farmers' perceptions of organic wastes as nutrient sources. To assess the adoption potential, it is useful to analyse changes in farmers' knowledge, attitudes, skills and aspirations towards compost as well as their WTP over time.

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2.3 Environmental Concerns of Urban and Peri-urban Agriculture: Case Studies from Accra and Kumasi

E. MENSAH¹, P. AMOAH², P. DRECHSEL²
and R.C. ABAIDOO³

¹Agricultural Engineering Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana; ²IWMI (formerly of IBSRAM), Ghana Subregional Office for West Africa, Kumasi, Ghana; ³Department of Biological Sciences, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Using results from case studies from Accra and Kumasi, Ghana, this chapter gives examples of environmental concerns related to: (i) water quality; (ii) the quality of waste stream products; (iii) food contamination; and (iv) the use of pesticides in urban and peri-urban agriculture.

Key words: West Africa, Ghana, urban agriculture, irrigation water, coliforms, composts, poultry manure, food contamination, pesticides

Introduction

The contribution of urban and peri-urban agriculture to food security appears to be quite appreciable in many developing countries like Ghana. It brings the produce close to the market thus reducing transportation distance and costs as well as related postharvest losses. Consequently, it is especially attractive for perishable crops, such as vegetables.

Vegetable cultivation takes place during all seasons and irrigation facilities are the most crucial site factor. Usually, seedbeds and fields are established in bottomlands, along city drains and other water bodies. A few of these farmers or gardeners dig wells at sites where the water table is high. Irrigation is usually done by sprinkling with watering cans; the water used is untreated. Besides water, production is also input intensive with respect to nutrients and pesticides, raising concerns about the impact of urban and peri-urban agriculture on the environment and human health (Birley and Lock, 1999).

The objective of this chapter is to address related problems by taking data from various studies carried out in Accra and Kumasi as examples.

Methodology

The chapter is based on results from several projects carried out by the authors and supplemented by data from other working groups and references. Samples of water bodies (streams, major drains, hand dug wells and ponds) used for vegetable irrigation in Kumasi and Accra were collected between 1992 and 1999 and analysed for pollution levels (Owusu, 1998; Mensah, 1999). Parameters analysed include total coliform counts, faecal coliforms, heavy metals, biochemical oxygen demand (BOD), nitrate, acidity alkalinity, salinity, total dissolved oxygen, etc. Different methods were used to determine coliform levels (faecal and non-faecal): the filter membrane and the multiple tube count methods as well as the *most probable number* (MPN) method. The dilute and incubation method was employed to determine BOD levels whilst an oxy-acetylene flame with *Impact Bead* was used for heavy metals with the exception of mercury and arsenic where the cold vapour technique and hydride system were used respectively.

For the analysis of total and faecal coliforms in poultry manure and vegetable (onion, lettuce, cabbage) samples the MPN method was used. Vegetable samples were taken in five farms and four markets within Kumasi.

Finally, a survey among 93 poultry farmers was carried out to obtain information on the potential chemical pollution of poultry litter as a result of bird disinfections.

Results

Quality of irrigation water

Akuffo (1998) reported that the development of basic infrastructural services such as water supply, sewerage and other sanitation facilities in many developing countries, including Ghana, lags behind urban growth. This creates problems for the maintenance of safe minimum standards of environmental quality in the urban environment.

In 1995, the total and uncontrolled BOD discharge into the environment in the Accra Metropolitan Area alone was about 72 t day^{-1} and is projected to reach about 167 t day^{-1} by 2020 if nothing is done about the situation. Domestic waste water represents by far the major source of the BOD load in the urban area (80–90%), followed by industrial effluents (Pwamang, 1998). Many of these polluted urban water bodies are used for the irrigation of crops. In these cases contamination with excreta (coliforms) needs special attention. Measurements carried out in Accra between 1992 and 1998 showed usually an *Escherichia coli* population size (Table 2.3.1) exceeding the threshold level of 1000 100 ml^{-1} for the irrigation of crops likely to be eaten raw (Westcot, 1997).

Table 2.3.1. Average pollution levels of selected parameters of sampled water bodies in Accra and Kumasi (1992 and 1998).

City	1998				1992–1998	
	Nitrate (mg l ⁻¹)	BOD (mg l ⁻¹)	COD (mg l ⁻¹)	TDS (mg kg ⁻¹)	Faecal coliforms (100 ml ⁻¹)	
Accra	BDL	46.7 (2.5)	116.3 (108.5)	904.7 (396.0)	3.5 × 10 ³ (21.9)	126.2 × 10 ⁴ (130.0)
Kumasi	BDL	20.7 (5.9)	28.3 (n.d.)	339.7 (198.2)	45 (5.5)	96.0 × 10 ³ (39.4)

Standard error in brackets.

BOD, biochemical oxygen demand; COD, chemical oxygen demand; TDS, total dissolved solids; BDL, below detection limit.

Results from Kumasi show that hand dug wells appeared to be less polluted (Table 2.3.2), which corresponds with data from Owusu (1998) but was not confirmed by Cornish *et al.* (1999). Cornish *et al.* (1999) emphasize the need for further analyses of a larger number of wells than considered so far.

Generally, the values of selected parameters measured in water samples from Accra were higher than those from Kumasi indicating higher water pollution levels (Tables 2.3.1 and 2.3.2). This could be attributed to sample location/time but also to higher population size, more industries, and inadequate sewerage and refuse disposal facilities and as a result the release or runoff of more waste (both domestic and industrial) into water bodies.

A closer look at Wiwi River (in Kumasi) shows large variation between the years (Table 2.3.3). For example, there was an increase in faecal coliform count of 45 100 ml⁻¹ (1998) to 14,800 100 ml⁻¹ (1999).

In particular, drains and streams are polluted heavily with faecal coliforms reaching 10,000–100,000 counts (Table 2.3.4). In all likelihood this is due to contamination with faecal matter. This corresponds with the precarious situation of Kumasi's sanitary service as described by Salifu and Mumuni (1998): Fewer than 4% of Kumasi's residents have access to sewerage, 40% of residents depend on public toilets, 15% on septic tanks, while fewer than 10% have household improved pit latrines. Cornish *et al.* (1999) found that levels of microbiological water pollution at all sites monitored downstream of Kumasi exceeded the FAO guidelines given by Westcot (1997) for unrestricted irrigation. Rivers upstream are relatively clean.

Heavy metal analysis in urban water bodies showed in general acceptable levels (Table 2.3.5), as confirmed by Cornish *et al.* (1999).

Impact of polluted water on food quality

The use of polluted water from drains, streams and hand dug wells, etc., could impact negatively on food quality as data from Accra show (Armar-Klemesu *et al.*, 1998). Environmental Management and Associates Ltd (1989) also

Table 2.3.2. Average values of bacteriological, physico-chemical and heavy metal analyses of waste water samples from Accra and Kumasi in 1998.

Parameter	Accra			Kumasi		
	Teshie ^a	Industrial area ^b	Tesano ^c	Kwadaso ^d	Chirapatre ^e	Wiweso (near UST) ^f
1. pH	7.45	7.57	6.94	6.93	54.41	6.55
2. TDS	682	1461	571	620	202	197
3. Salinity (Cl ⁻¹) (mg l ⁻¹)	0.1	0.7	0.1	0.1	0.0	0.0
4. Nitrate (mg l ⁻¹)	BDL	BDL	BDL	BDL	BDL	BDL
5. BOD (mg l ⁻¹)	46.0	50.0	44.0	18.0	25.5	29.0
6. COD (mg l ⁻¹)	54.4	268.8	25.6	28.32	0.0	28.32
7. Electrical conductivity (mS cm ⁻¹)	0.78	1.670	0.650	0.618	0.201	0.199
8. <i>E. coli</i> 100 ml ⁻¹ water	3100	1100	6400	0	0	45
9. Coliforms 100 ml ⁻¹ water	> 3000	> 3000	> 3000	> 1500	< 1500	> 1500
10. K (mg l ⁻¹)	21.00	30.10	13.00	13.30	10.40	12.20
11. Mn (mg l ⁻¹)	0.36	0.21	0.24	0.69	0.12	0.01
12. Fe (mg l ⁻¹)	0.98	1.73	0.03	10.70	1.43	1.50
13. Al (mg l ⁻¹)	0.20	0.40	0.00	0.00	0.50	0.00
14. Na (mg l ⁻¹)	55.10	135.90	45.90	34.50	10.20	5.50
15. Pb (mg l ⁻¹)	0.05	0.02	0.00	0.00	0.03	0.00

^a Surface streams polluted with sewage; ^b Industrial waste water (textiles, chemicals, and oil); ^c Drains (domestic waste water); ^d Hand dug well;

^e Hand-dug well; ^f Streams polluted with domestic waste.

KNUST, Kwame Nkrumah University of Science and Technology; BDL, below detection limit; TDS, total dissolved solids; BOD, biochemical oxygen demand; COD, chemical oxygen demand.

Table 2.3.3. Average values of bacteriological, physical and chemical analyses of irrigation water from Wiwi River in Kumasi.

Parameter	1998	1999
pH	6.55	6.83
TDS (mg kg ⁻¹)	197	39.2
Nitrate (mg l ⁻¹)	BDL	n.d.
Conductance (mS cm ⁻¹)	0.20	39.68
Faecal coliform (100 ml ⁻¹)	45	14,800
Total coliforms (100 ml ⁻¹)	> 1,500	33,200

TDS, total dissolved solids; BDL, below detection limit.

Table 2.3.4. Average values of coliforms of irrigation water bodies sampled in Accra (1992).

Source of water	Total coliforms 100 ml ⁻¹	Faecal coliforms 100 ml ⁻¹
Drains	$4.9 \times 10^3 - 3.5 \times 10^7$	$4.8 \times 10^3 - 2.8 \times 10^6$
Streams	$3.1 \times 10^5 - 3.5 \times 10^7$	$3.9 \times 10^2 - 3.5 \times 10^5$

Table 2.3.5. Average values of heavy metal levels sampled in 1998 and 1999 in water bodies used for irrigation in Accra and Kumasi (mg l⁻¹).

Element	Threshold ^a	Concentration
Ni	0.20	0.03
Hg	0.50	0.05
Cr	0.10	0.02
Pb	5.0	0.03–0.11
Mn	0.20	0.27–0.93
Cu	0.20	0.05
Cd	0.01	0.006
As	0.10	0.003
Fe	5.0	0.9–4.5

^a Recommended maximum concentration for crop irrigation (Pescod, 1992).

uncovered high levels of faecal contamination both in water and in lettuce and cabbage leaves irrigated with polluted water from sites in Accra. The permissible residual levels of faecal and non-faecal coliforms on vegetables have not been established finally; however, according to the International Commission on Microbiological Specifications for Food (ICMSF) guideline (Cornish *et al.*, 1999), analyses of sampled vegetables showed in general undesirable but still acceptable residual levels on the edible parts of vegetables (Table 2.3.6). The levels correspond to the high levels of total and faecal coliforms in the irrigation water used, with higher values found near drains. Crop contamination needs special attention for those vegetables eaten raw, such as lettuce and cucumber, while most others are usually cooked.

Table 2.3.6. Average numbers of faecal coliforms on sampled vegetables from eight production sites in Accra (1992).

Sources of water for irrigation	Lettuce	Onion	Carrot
Drains	$1.1 \times 10^3 - 34.7 \times 10^3$	$1.2 \times 10^3 - 33.9 \times 10^3$	$1.5 \times 10^3 - 36.1 \times 10^3$
Streams	$1.6 \times 10^3 - 9.2 \times 10^3$	$1.2 \times 10^3 - 15.5 \times 10^3$	$1.6 \times 10^3 - 16.1 \times 10^3$
ICMSF guideline:	$> 1 \times 10^3$ <i>E. coli</i> type 1 100 g ⁻¹ fresh weight is 'undesirable' $> 1 \times 10^5$ <i>E. coli</i> type 1 100 g ⁻¹ fresh weight is 'unacceptable'		

Thoroughly washing the crop surface with clean water significantly reduces the level of contamination (Cornish *et al.*, 1999).

If vegetables are not washed properly before being eaten, the use of such polluted water bodies for irrigation could possibly pose epidemiological problems, as also nematode eggs have been detected in sampled water bodies including shallow or hand-dug wells (Cornish *et al.*, 1999). The high number of eggs in the shallow wells indicates that wells do not necessarily guarantee better quality water than that drawn from polluted streams and drains.

Quality of nutrient sources and contamination risk

Compost quality

Besides its fertilizer value and impact on soil structure, we have to consider the risk of microbiological and/or heavy metal contamination when using compost made from urban waste. Batteries especially can contribute to mercury (Hg) and cadmium (Cd) pollution. The sieving process currently used in Ghanaian compost plants is not able to exclude batteries, and sewage sludge might also be contaminated. Gerner *et al.* (1995) point out that the sewage sludge produced in northern Accra (Achimota) has not only a higher nutrient content than the compost from Accra's Compost Plant in Teshie, but also higher heavy metal concentrations. Compost analyses from the Teshie Compost Plant as reported by Etuah-Jackson *et al.* (Chapter 3.2, this volume) show Hg concentrations ($0.34\text{--}0.78 \text{ mg kg}^{-1}$) exceeding typical values analysed in the UK ($0.05\text{--}0.33 \text{ mg kg}^{-1}$). However, the values are still acceptable ($< 2\text{--}4 \text{ mg kg}^{-1}$). The other data including the coliform counts do not indicate any risk. However, as with all environmental analyses, snapshot analyses can only give indications; measurements over longer time periods will be necessary to give a more reliable picture of the compost quality.

Poultry manure quality

Around Kumasi there are numerous poultry farms, and poultry litter has usually been considered as waste and dumped or burnt along roadsides (Drechsel, 1996). However, farmers have become more aware of its fertilizer value and

the use of poultry manure (and where available cow dung) is catching on quickly within the peri-urban vegetable production communities, particularly around Kumasi where poultry density is high. Application is repeated: for vegetable beds the litter is mixed with the soil, for older vegetables broadcasting is common. Two potential sources of manure and subsequent food contamination have been identified:

1. From our survey it was observed that 65% of the 93 poultry farmers interviewed use pesticides to either spray the birds (and the litter) or the birds are dipped in a chemical solution. Mostly, chemicals such as *gamma-HCH*, *sulphur*, *pirimiphos-methyl*, *trichlorphon*, or *Supermix* are used; therefore the probability that the manure is contaminated with such insecticides is high. Especially, these chemicals might contaminate vegetables with large surfaces, such as lettuce. In addition, water bodies nearby may be affected through runoff.
2. Fresh litter samples usually show high numbers of total and faecal coliforms while (older) heaped samples have little *E. coli* contamination. For example faecal coliform count of fresh poultry litter samples detected in Kumasi (1999), ranged between 3.6×10^4 and 1.1×10^7 (Table 2.3.7). The numbers in heaped samples were lower ($0-3.0 \times 10^4$).

Microbiological activities in heaped poultry litter resulted in an increase in temperature high enough to reduce the number of coliforms. In practice, however, sufficient composting is rare. With increasing demand for poultry manure, vegetable farmers are competing for the litter. They started to offer poultry farmers fresh bedding material (usually wood shavings) in exchange for manure enriched litter. Thus, the majority of poultry farmers who give the litter to crop farmers do not store it before it leaves the farm. Also virtually no crop farmers who asked for litter enquired about its maturity. After collection, about 60% apply the poultry litter directly without further composting while 40% heap the litter for some weeks or more (Figure 2.3.1) depending on the date they need it on their fields. It appeared that poultry litter is frequently applied without adequate composting thus constituting a potential source of food contamination.

Food contamination through poultry manure

In particular, food contamination concerns leafy vegetables as every second farmer broadcasts the litter over already established crops. During irrigation, the litter is largely washed down, however, farmgate samples of lettuce,

Table 2.3.7. Average values of levels of coliforms detected in poultry litter samples from some poultry farms around Kumasi.

Parameter	Fresh litter	Heaped litter
Total coliforms (100 ml ⁻¹)	$2.6 \times 10^5 - 1.1 \times 10^8$	$0-3.0 \times 10^4$
Faecal coliforms (100 ml ⁻¹)	$3.6 \times 10^4 - 1.1 \times 10^7$	$0-3.0 \times 10^4$

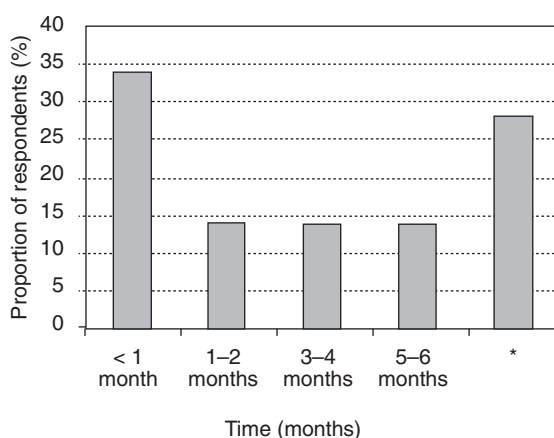


Fig. 2.3.1. Storage period of poultry litter by crop farmers who heap it for some time before use. *, no specific period of time.

cabbage and onions from poultry manure treated fields still contained high levels of total and faecal coliforms (Table 2.3.8).

Vegetable samples not treated with poultry manure in all cases had lower coliform counts but were still affected due to contaminated irrigation water. The farms studied used water from ponds, wells, streams or drains with up to 35×10^4 counts of faecal coliforms per 100 ml. This source of contamination can be important (as discussed above) but might be – at least in part – home-made by (peri)urban agriculture through excessive application or dumping of poultry manure. In the Accra plains, for example, Barnes *et al.* (1993) analysed high counts of faecal coliforms especially in boreholes located in cattle rearing areas.

Vegetables analysed on major markets in Kumasi did not show significantly different coliform counts than the farmgate samples (Table 2.3.9). Whether coliforms from manure application were still present, depended on the frequency of manure application and the survival time of faecal coliforms on crops (< 30 but usually < 15 days; Westcot, 1997). While many lettuce

Table 2.3.8. Faecal coliform counts of vegetable samples from various farms in Kumasi (MPN 100 ml⁻¹).

Sample	Average ($\times 10^4$)	Range ($\times 10^4$)
Lettuce	22.7	2.9 – 50.0
Cabbage	8.8	1.9 – 17.5
Onion	4.1	1.5 – 7.8

MPN, most probable number; results per 5 g of sample.

farmers apply the manure only once, cabbage and onions receive their first treatment 1–2 weeks after planting and another treatment 3–4 weeks before harvest. In these cases a carry-over of coliforms is possible. The finding that the market samples did not show significantly different coliform counts from the farmgate samples not only indicates that there was no additional contamination through market related handling, but also no impact of on-market vegetable washing. In a comparable study carried out in Accra, Armar-Klimesu *et al.* (1998) found higher coliform contamination of market samples than in farmgate samples, however, also in this case the major source of contamination appeared to be the farm and probably the water used for irrigation.

There were significant differences between the various markets in Kumasi (Table 2.3.9). The relatively lowest contamination was found in Adum market which is frequently visited by expatriates. Here the sellers washed most of their products more frequently, intensively, and with fresh water each time, than their colleagues in the other markets. The sellers argued that the 'Whites' (expatriates) only buy very clean and visually attractive products.

Soil and water eutrophication through poultry manure and industrial fertilizer

High application rates of fertilizer or poultry manure, especially in bottomlands and near streams, bear the risk of (groundwater) pollution. Probably due to the few sites or projects with large-scale fertilization in the study area, related information is rare. Studies carried out by Zickermann *et al.* (1998) showed, that an environmental impact is unlikely on coarse loamy Typic Paleustults, which are common around Kumasi, with recommended moderate application rates of poultry manure (4 t ha⁻¹ on maize–cassava fields). The results showed also a quick vertical transport in the soil of nitrate and ammonium from mineral fertilizer (NPK and (NH₄)₂SO₄: 60:40:40 kg NPK). Vegetable farmers, however, often apply much larger amounts of, for example, 30 t poultry manure ha⁻¹. In areas with commercial vegetable production, such as Agogo or Akumadan (both in Ashanti Region), we noticed water body eutrophication through runoff (cf. Kyei-Baffour and Mensah, 1993).

Table 2.3.9. Faecal coliform counts of vegetable samples from markets in Kumasi (MPN 100 ml⁻¹).

Sample	Ayigya Market	Asafo Market	Kejetia (Central market)	Adum (Post office)
Lettuce	21.7×10^4	9.9×10^4	40.3×10^4	0.90×10^4
Cabbage	14.1×10^4	7.6×10^4	22.6×10^4	0.73×10^4
Onion	7.8×10^4	5×10^4	18.6×10^4	0.57×10^4

MPN, most probable number; results in washing water from 5 g of sample.

The general picture around Kumasi shows increased nitrogen levels downstream of the city (but only traces of nitrate) and generally high phosphate levels (Cornish *et al.*, 1999). Rainfall events largely influenced the values over the period of sampling, indicating urban runoff and the early mineralization flush as reasons. With respect to crop irrigation the authors do not see any threat. In contrast, it appears that the polluted water downstream of Kumasi makes a significant contribution to the nitrogen requirements of irrigated crops.

Other inputs (pesticides)

Vegetable diseases and pests are being managed in Ghana mainly through the application of pesticides. Especially in peri-urban areas and in vegetable production the use of pesticides is common (Table 2.3.10). But also poultry are often treated with insecticides instead of medicine, resulting probably in manure contamination (see above). In a cross-country study carried out by Nurah (1999) all the dry season vegetable farmers interviewed reported spraying their crops with fungicides or insecticides. The number of sprayings was variable but generally less frequent than in the rainy seasons. The use of herbicides to control weeds is less common than the use of pesticides and depends in part on regional labour wage rates (Nurah, 1999).

Careless application of pesticides poses various health problems to farmers in Ghana (Kyei-Baffour and Mensah, 1993; Clarke *et al.*, 1997; Ntow, 1998) ranging from skin rashes and skin irritations to sexual disability and even the death of children through mishandling of insecticides which occurred in 1999. Recently, the Water Research Institute (WRI) in Accra has mounted a sampling programme to analyse quantitatively pesticide concentrations at various levels of the food chain as well as the environment in Akumadan, a prominent tomato production area near Kumasi (Ntow, 1998).

The study found pesticide residues not only in water and sediment samples, but also in human blood and breast milk of tomato farmers (Ntow, 2001).

Among all vegetable crops, the highest tendency to pesticide overuse was observed for tomato. Around Akumadan, application takes place all 5–7 days

Table 2.3.10. Input use for peri-urban villages around Kumasi.

Input	Percentage of peri-urban villages where at least some farmers use the input
Chemical fertilizer	91
Insecticides	85
Fungicides	64
Herbicides	57

Source: Nsiah-Gyabaah and Adam (Chapter 3.3, this volume).

during the 3-month production period, also during harvest. The majority of the Ghanaian farmers interviewed in a pesticide-use field survey (Table 2.3.11) knew of health problems associated with pesticides. The most serious problems farmers associated with pesticide use were general ill health, acute poisoning and phytotoxicity. More literate farmers observed phytotoxicity problems, while poisoning was a phenomenon more common among the illiterate farmers (Gerken *et al.*, 2000). Farmers listed the following acute poisoning symptoms: headache; general weakness and dizziness; body pains; nausea and vomiting, stomach-ache and diarrhoea. Only 12% of the respondents, mostly medium- and large-scale farmers, did not use any protective equipment. The main protective items mentioned by the farmers were long trousers, long sleeved shirts and wellington boots.

Increased risk of malaria through urban agriculture?

There are concerns that open spaces in African cities used for farming increase the risk of malaria. This concerns especially cities with swampy valley bottoms and *Anopheles gambiae*, one of the main malaria vector species, which breeds in all kinds of small temporary pools or puddles – typically sunlit, shallow, muddy and clean. The demand for clean water usually limits the spread of malaria in urban centres, however, *A. gambiae* appears to have become more adapted to polluted conditions as reports from Accra show (Chinery, 1984).

Anopheles requires at least 5 days for breeding. This goes beyond usual infiltration times after irrigation. The exception is paddy rice, which is (in this sense fortunately) rare in and around Kumasi and Accra. However, garden ponds, wells or just puddles of water along streams or in fields with clay soil may also function as breeding sites (Birley and Lock, 1999). Studies to verify the significance of these concerns have been initiated.

Table 2.3.11. Problems with pesticide use per level of education (in percentages of interviewed farmers, multiple answers possible).

Problems	Level of education		
	No formal	Primary	Tertiary
Phytotoxicity (burning of plants)	12.9	21.2	28.6
Feeling sick after spraying	41.9	40.0	42.9
Poisoning	46.8	10.6	10.2
None	30.6	50.6	46.9
Total	132.2	122.4	128.6

Source: Gerken *et al.* (2000).

Conclusion

Peri-urban and urban vegetable production is a desirable activity with many advantages for producers and consumers but is also associated with certain risks. Farming often takes place under hazardous conditions, especially with respect to the quality of irrigation water. There is widespread evidence of water contamination mostly with coliforms. Often it is difficult to identify the exact sources of the problem or they are difficult to detect, e.g. organic pollutants, with the equipment available. Farmers' access to clean water should be given more attention, however, under consideration of farmers' possible contribution to water contamination.

Snapshot analyses cannot give the farmer or consumer any security as pollution levels can vary significantly between different sampling periods (see Table 2.3.3). Besides more education of vegetable growers on the safe use of inputs, environmental monitoring programmes are desirable – at least at each of the well-known commercial crop production sites – to assess as often as possible the actual quality of inputs, such as compost and water, as well as outputs (crops), and to counteract any environmental contamination and impact on the consumers as early as possible. Such programmes should also address the potentially increased malaria risk through agriculture in urban areas.

Interventions to prevent the spread of gastro-intestinal infection should, however, also focus on the consumer household, its awareness on the problem of food contamination, the need for vegetable washing and households' access to piped water. Still a large part of the urban population, even in the capital of Accra, has no access to in-house piping and relies on informal water vendors for their daily water supply.

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Turning Urban Waste into Fertilizer for Urban and Peri-urban Farmers: Case Studies from East and West Africa

3.1 Ibadan

TURNING MUNICIPAL WASTE INTO COMPOST: THE CASE OF IBADAN

Tunde Agbola

*Center for Urban and Regional Planning, University of Ibadan,
Ibadan, Nigeria*

This chapter gives an introduction into the problems of solid waste management in Ibadan, Nigeria, and describes the Bodija composting plant, which started operation in 1998.

Key words: West Africa, Nigeria, municipal wastes, composts

Introduction

One of the most intractable but unavoidable urban services in developed and developing countries is the management of solid waste generated within cities. While the developed countries have long been aware of waste problems and have evolved necessary management processes to deal with them, developing nations are still grappling, most unsuccessfully, with the same sets of problems. The rate of urbanization especially has given rise to the immense and ever-increasing amount of solid wastes generated, so much so that these

wastes have long outstripped the capacity of nature to assimilate them and of city authorities to collect and dispose of them safely and efficiently. In Nigeria's exploding mega-cities of Lagos and Ibadan, sustainable solid waste management (SWM) will be of major importance for their overall development. With an estimated national per capita generation rate of about 150 kg year⁻¹ (PAI, 1982), about 16 million and 22 million t of solid waste would be generated in 1998 and by 2010, respectively. With support from the United Nations Centre for Human Settlements, (UNCHS) Sustainable Cities Programme (HABITAT), a compost plant first started operation in 1998. It is the aim of this chapter to showcase this project in the context of SWM in Ibadan. Ibadan is located about 145 km northeast from Lagos. The 1991 census gave the city's population as 2.8 million people. However, this figure has been contested hotly by the government of Oyo State as a gross underestimate.

Methodology

Various scholars and researchers have worked on the different processes of SWM in various cities in Nigeria and in Ibadan in particular (Adedibu, 1983; Egunjobi, 1986, 1992; Ogu, 1987; Ipadeola, 1988; Olokesusi, 1991; among others). Therefore, this chapter has benefited from these sources by conducting an intensive literature search divided into discrete elements on the subject. Accordingly, the generation, collection, storage, transportation, disposal and environmental impacts of solid wastes were searched for and collated.

However, since this chapter focuses on a particular case study, it became necessary to obtain detailed information on the Bodija composting plant. Many different structured interview sessions were conducted with the project manager of the Sustainable Ibadan Project (SIP), the originator of the project and the project manager of the Bodija composting plant who represents the Oyo State Government (the financier of the plant) and the Oyo State Environmental Protection Agency. These interviews and the literature search form the basis of this chapter.

The Status Quo of SWM in Ibadan

Waste generation

Various attempts have been made by scholars, researchers, consultants and governments to determine the actual amount of wastes being generated in Nigeria in general and Ibadan in particular. A consultant firm appointed by the World Health Organization in 1970 to carry out a study on the sewage, drainage and solid waste for Ibadan, estimated a generation rate of between 0.37–0.5 kg per capita day⁻¹ for the core areas of the city and 0.53 kg per capita day⁻¹ for the newer areas (Maclaren, 1970). Also Oluwande (1974)

estimated generation rates of between 0.4 and 0.54 kg per head and day for different parts of Ibadan. PAI (1982) estimated a generation rate of 3.4 kg per household day⁻¹ in the core areas and 3.2 kg per household day⁻¹ in the newer areas of the city. Given an average of 3.3 per household day⁻¹ and an estimate of eight people per household for the whole city, a generation rate of 0.39 kg per capita day⁻¹ was deduced. However, with the unabated increase in the rate of urbanization, the city's waste management authority has been using an operational estimate of 0.6 kg per person day⁻¹.

From the perspective of Ayodele (1993), the weight per person of solid waste generated in Ibadan city is 0.4–0.6 kg day⁻¹. Therefore, the estimated waste generated in the city daily is 80 t. Whereas PAI (1982) estimated the annual rate of solid waste generation in Ibadan as being about 397,000 t, the Ibadan Waste Management Committee in 1993 put the value at over 751,000 t year⁻¹. This increase in the solid waste generation rate could be attributed to rapid population growth, different per capita estimates (see above), increased consumption pattern, and the intensified functional position of Ibadan as an administrative, commercial, industrial and institutional centre.

Waste composition

The composition of solid waste in Ibadan is similar to that found in other Nigerian traditional towns. However, the increasing role of Ibadan city as well as its function as a major bulk-breaking centre, has further aggravated the rate of waste generation. Wastes generated in the city are more organic than inorganic. In recent years, however, with increased diversification of the economy and consumption, SWM of industrial goods such as non-biodegradable materials, the inorganic content of the city's wastes has increased steadily. Given this development and the various structural adjustment policies of the government, people and industrialists should now be looking inward by recycling some of the inorganic materials for re-use. This would be beneficial, especially if the issue of cost of financing SWM is taken into proper consideration.

Financing SWM

The cost of SWM in Ibadan has been increasing progressively over time. In 1991, it cost over ₦6 million¹ to manage waste in Ibadan. This figure rose to more than ₦10 million in 1994. The available funds for SWM are grossly inadequate simply because of the capital-intensive nature of the exercise. According to the Ibadan Urban Sanitation Committee, a sum of about ₦80 million yearly was required for efficient and functional waste collection, storage, transportation, processing and disposal in Ibadan.

¹(US\$1.00 = ₦100).

Besides the financial support received from the state government and the money accruing to Ibadan Solid Waste Management Authority through dues and licences, other agencies are supportive in kind. These include the Oyo State Environmental Protection Commission, which assists with the supply of vehicles and equipment, and the Oyo State Local Government Service Commission that assists with the supply of personnel.

The institutional responsibility for SWM in Ibadan is complex and has changed several times over the last 30 years, always in the hope of achieving a more efficient impact than before (Table 3.1.1).

Perhaps an explanation for the inability of the government to manage solid waste in Ibadan effectively arose from the misconception of solid waste disposal as a cheap social service. By the current method of waste collection, transportation and disposal, each component of its operation is capital intensive, especially, in the area of equipment and vehicle procurement and running cost. By a 1988 calculation for example, a skip vehicle cost ₦0.2 million. In 1995, the same vehicle would have cost approximately ₦15 million. According to some estimates, 196 of such vehicles will be needed for excellent SWM operation in Ibadan.

This amounts to some ₦2.94 billion. This is only a sub-unit of the three main components (collection, transfer/haulage and landfill) of waste management. The total sum of the project runs into several billions of naira. Certainly, this is beyond the capacity of any local government and/or state resources since there are competing areas of need with solid waste. What is more, both the government and its agencies do not engage in preventive management. The sheer weight of the problem and institutions' own financial and technical inadequacies simply allow for emergency collection services, which are often not sustainable.

Due to the huge investment of capital required for effective solid management in Ibadan, various institutions (at various times) saddled with the responsibility of SWM have not been able to get rid of the solid waste problems. The problem of finance has always remained a major constraint to activities and performance. It would, therefore, be reasonable to review the activities of various institutions responsible for SWM in Ibadan over the years.

Table 3.1.1. Organizational change in SWM in Ibadan (1972–1999).

Period	Management agency
Period 1972	Ibadan City Council (Ibadan Municipal Government)
1973–1978	Ibadan Waste Disposal Board
1984–1989	Department of Sewage and Refuse Matter/Environmental Task Force/IMG/Private Firms
1989–1991	IMG/Private Firms/Environmental Protection Commission
1991–1997	Ibadan Urban Sanitation Committee/Environmental Protection Commission/Private Firms
1997 to date	Ibadan Solid Waste Authority/Environmental Protection Commission/Private Firms

Various other operational problems beset the management of waste in the city region such as location of waste collection points, transportation, winding road networks especially in the core areas, inadequate personnel and poor remuneration, etc.

The sum total of these ineffectual arrangements and operational problems is the continued environmental degradation of the city as manifested in unsatisfactory SWM, water pollution (surface and underground), air pollution (through indiscriminate burning), reduction of property value, health hazards (waste-borne, food-borne and vector-borne communicable diseases). Fumes from refuse burning worsen bronchial and asthmatic disorders while flooding occurs when refuse is dumped in water drainage and stream courses. Regrettably, an environmentally poor society further endangers societal public health, increases spending on health matters, and reduces spending on other expenditure categories.

To make the situation worse, the locations of the dumping sites (erroneously called sanitation landfills) are sub-optimal. Today, only one site is being used for the entire city with obvious consequences for waste management effectiveness. Even this site is facing community opposition as the adjoining villages' water, land and air have been polluted severely (Agbola, 1989). With problems arising from all sectors, it has become imperative to find a sustainable solution to the SWM problem of Ibadan. This is why the composting option for the use of solid wastes is not only timely, but holds immeasurable potential to solving many problems together.

Composting is feasible or practical in the sense that municipal waste is usually rich in organic matter. It is viable or profitable in the sense that it reduces landfill costs, and that bio-humus for agricultural production and biogas for domestic lighting and cooking can be sold locally or exported for profit. It is environmentally friendly as it conserves natural resources and protects the environment. The multiple effects of composting are therefore many. Composting provides employment in the production process and ancillary activities, boosts savings in foreign exchange through reduced import of fertilizer, encourages trade and promotes tourism through a cleaner environment.

The case study reported here is the conversion of huge quantities of refuse into valuable resources, which help to alleviate poverty in the city region.

The Bodija Composting Plant

The antecedents

The Bodija composting plant owes its initiation and origin to the SIP Waste Working Group. The SIP is the operational arm of the Sustainable Cities Programme, a major UNCHS (HABITAT) initiative for promoting and supporting sustainable development in cities and towns around the world.

A major component of SWM is the disposal of waste. In Ibadan, a solid waste disposal site is located at Aba-Eku along Ibadan-Akanra-Ijebu-Igbo

Road. Open dumping is practised at the site. It is unsightly, hardly accessible, and blocked by waste. The minimum technical requirements for this activity such as bottom and lateral sealing are absent and the waste is not subjected to any treatment before or on the disposal site. Consequently, the area is polluted by leachate and putrefied matter (Olokesusi, 1991).

The above problems, which militate against effective and efficient SWM in the metropolitan area, led the SIP to adopt the Environmental Planning Management (EPM) process in its management approach to solving the city's solid waste problem, using the Bodija Market as an experimental project site. The EPM process is a succession of basic steps needed to carry out environmental management plans. It is designed to make the formulation and implementation of environmental policies more responsive to environmental consideration. It is an articulated analytical framework and logical structure, which facilitates better understanding of the dynamism of urban development and environmental issues and helps in evolving guidelines for intervention.

The process can be distinguished from the traditional planning approach in that it seeks and ensures consensus among stakeholders and actors on the environmental strategy that may evolve. Important instruments are stakeholder working groups. The waste working group of the SIP has 17 members (SIP, 1998). Its focus is on the process of waste generation, collection, transportation, disposal, and recycling. According to SIP management, many market traders who wish to avoid payment of service charges collected by Ibadan SWM Authority officials for using the mobile collection facilities, usually dump their wastes illegally and burn them in the open (SIP, 1998). This is due to the poor environmental education of the traders.

With the magnitude of SWM in the city and with the advent of SIP, there was a move to take action. This met approval with the Oyo State Government, which had been looking for a way to deal with the waste problem. SIP was asked to prepare a proposal under the guidance of Professor M.K.C. Sridhar, a Professor of Public Health in the Department of Preventive and Social Medicine in the University College Hospital, Ibadan. With the interest of the state government, a composting and an organic fertilizer production plant was established at Bodija Market. Thus, the SIP working group (facilitated by the Oyo State Government) initiated the pace-setting fertilizer composting plant at Bodija Market (Omueti *et al.*, 2000).

Sourcing funds for the project

A total sum of ₦6.4 million was spent on the organo-mineral fertilizer plant project at Bodija. The machinery has a lifespan of 15 years and cost about ₦1.5 million. In addition, the physical structure costs close to ₦3.0 million to complete.

The initial intention was to co-share the project cost with the Bodija community and the local governments in Ibadan. This was the initial concept by

the SIP to sustain the project and let the community feel a sense of ownership. However, in order to act fast and to lead by example, the Oyo State Government decided to carry on and the construction was completed within three months.

Construction of the plant

All the machinery installed and used at the composting plant was made locally by the University of Ibadan.

Equipment comprises a pulverizer conveyor I, a pulverizer conveyor II, a mixer conveyor, a mixer sorter conveyor and a sorter. Thus, there are four principal components:

- the rotring screen/sorter;
- the pulverizer;
- the mixer; and
- the bagging/storage component.

The machinery uses eight motors. The plant has a daily capacity of processing about 20–22 t of wastes to about 8–9 t of finished product in a single shift of 10 h.

The project was commissioned on 16 July 1998 and the product is called Pace-setter Organic Fertilizer since the state (Oyo State) where the plant is located is a pace-setting state.

Operation management

There are three categories of staff. The personnel complement of the plant is shown in Table 3.1.2.

The unskilled personnel form 70% of the work force and since the work is 90% manual, the greater the number of labourers, the higher the quantity produced will be. Presently, on many occasions, the chambers cannot be filled due to lack of labour input for sourcing materials. This is why it is necessary to increase labour by 300% to meet the designed capacity.

Since the process is 90% manual, the equipment needed is essentially wheelbarrows, shovels, forks, brooms, gloves and facemasks. However, only one-third of the amount needed for optimal performance is available or provided currently. If desired, the process could be more mechanized.

Table 3.1.2. Plant personnel.

	Present	Required
Skilled (project manager)	1	3
Semi-skilled (technician)	1	3
Unskilled (casuals)	20	60

The production process

There are three major stages in the composting of wastes in Bodija into organic fertilizer. First is the manual sorting of waste into various components (Fig. 3.1.1). About 30 kg of waste are turned into 10 kg of fertilizer. The sorting of wastes into various components takes place in the sorting bay. The sort-

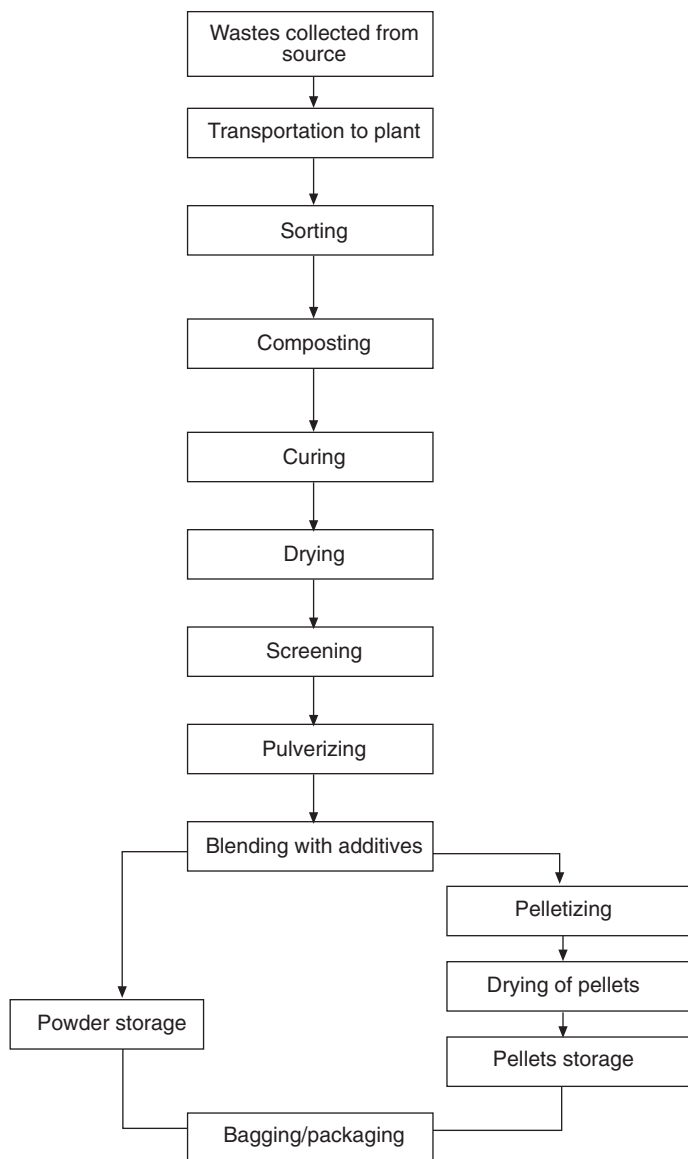


Fig. 3.1.1. Process flow chart of the Pace-setter Fertilizer Plant.

ing bay consists of three chambers. These chambers are for sorting sawdust, animal wastes and market wastes respectively. Waste is transported from the central dumping site to the storage pit and later transferred to the sorting bay. The sorting is done rudimentarily using simple tools such as wheelbarrows, shovels, headpans and handgloves, to sieve or remove the non-biodegradable wastes from the biodegradable wastes.

The second stage takes place at the processing chamber which consists of composting and curing windrows. After sorting wastes (into different categories), market and animal wastes are mixed at a ratio of 3:1 while water is added to form paste. Thereafter, the waste is moved to the processing chamber, which is made up of several chambers labelled alphabetically for identification. In the plant, there are 18 composting windrows on either side making a total of 36. Moreover, there are three curing chambers on either side of the curing section making a total of six curing chambers (Fig. 3.1.2).

The waste is kept for 20 days in each chamber and it is turned four times so that it eventually decomposes. Within this period, the wastes are continually turned by the labourers to ensure that the process of aerobic dehydration is thorough. On the 20th day, all of the waste is put in three curing chambers on each side for up to 2 months to ensure proper stability and maturity of the compost. The waste components are usually sun-dried before being transferred to the composting machine or plant.

The third stage involving the composting plant is the fulcrum of the entire process. Here, waste from the second stage is moved to the mechanical screening machine so the waste that escapes in the initial sorting is removed before sending the rest to the pulverizer and mill mixers to be reduced to granules (Fig. 3.1.3).

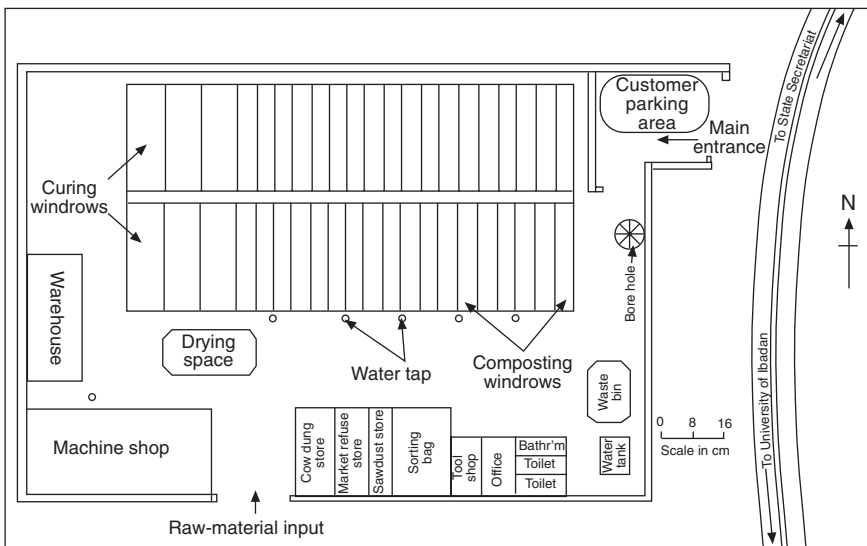


Fig. 3.1.2. Plant layout of the Pace-setter Fertilizer Plant.

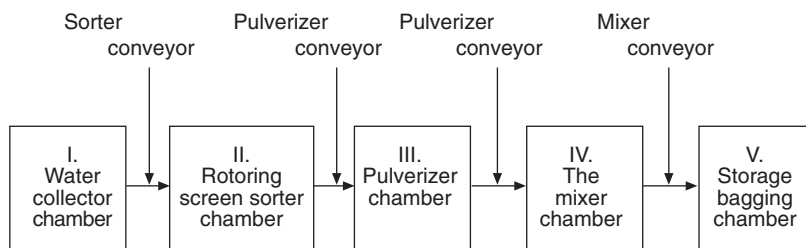


Fig. 3.1.3. Components of the organo-mineral fertilizer plant.

The sorter chamber contains a sorter conveyor. Wastes collected from the waste collector chamber are put into the sorter conveyor. The sorter automatically sorts or sieves all substances that cannot be crushed. The crushable element is transferred mechanically via the pulverizer conveyor I into the pulverizer. The pulverizer accepts crushed waste components. These are then reduced to fine powder and dust. Water is added usually to reduce the dust particles emanating from pulverizer conveyor II to the mixing chamber, where the fine powder is mixed with chemicals to give the final product. The mixer can produce powder or pellets depending on the choice. The products are then transferred to the temporary storage and bagging chamber through the mixer conveyor. The bagging chamber is the final stage in the process where the final products are bagged in 50 kg bags. The bagging chamber has a bagging capacity of about 200 bags per day.

Quality control

Quality is ascertained through the State Environmental Protection Authority Laboratory analysis to ensure the necessary nutrient balance or combination, especially N, P, and K. The international minimum ratio for NPK is 1:5:1. While this varies from area to area, the Bodija plant tries to maintain and even exceed this. In a recent comparison made with other fertilizers in the country, the Pace-setter Organic Fertilizer was judged the best in its range.

In a bid to ascertain the quality of the compost and to find adequate application rates, organic and inorganic fertilizer were applied to maize on a pilot project farm. The yields were significantly higher in the compost treatment.

Marketing

Oyo State is an agricultural state and Pace-setter fertilizer is marketed through distribution channels for inorganic fertilizer, which the state government purchases in bulk and distributes to farmers.

Marketing is done through the Oyo State Agricultural Supply and Input Company (OYSASIC) with headquarters in Oyo (a town about 30 miles north

of Ibadan); it is the sole buyer and distributor of the fertilizer. All buyers in the state are referred to OYSASIC (Fig. 3.1.4). OYSASIC pays for about 1000 bags (₦250,000) at a time and collects the compost for onward distribution. The product is sold at ₦250 50 kg⁻¹ bag to cover cost of production. There is a high demand as the inorganic fertilizer is sold at ₦1450 50 kg⁻¹ bag and the compost is equal to or better than inorganic fertilizer in quality, so much so that the plant is unable to meet the demand.

The composting plant produces an average of 80 bags day⁻¹. This supply is very small when compared with the demand and the demand may increase: urban agriculture along the main riverbanks and alluvial plains in Ibadan is still rudimentary. As the use of the compost becomes more popular, it is expected that many more farmers who cannot afford the industrial fertilizer will take advantage of this product. The implication is that the high demand coupled with low supply will influence the upward rise of the price of product. If the increase is reasonable, consumers will continue to buy from the OYSASIC which buys in bulk from the plant. On the other hand, if the price is too high, then consumers will shift their attention from buying this product to other competing inorganic fertilizer. In order to achieve a price equilibrium, there is an urgent need to double the workforce since the plant is capable of producing thrice the present production if night shifts are introduced. Research into how to increase production as well as allocation efficiency in the marketing of the product is receiving attention.

Government instability affects the production process. For example, owing to a change in government, accounts of government parastatals were frozen to check financial malpractices. Since OYSASIC is a parastatal, its accounts were frozen, making it difficult for it to pay for the product. As the only accredited buyer, this means no production since there will be no buyer. Fortunately, the government has realized that this is not good for the government purse and image and it is also not good for the many farmers who are interested in the product. There is now a move to allow the plant to sell to anyone.

Similarly, there is a plan to introduce a second line of production since raw materials are surplus and are not likely to be in short supply.

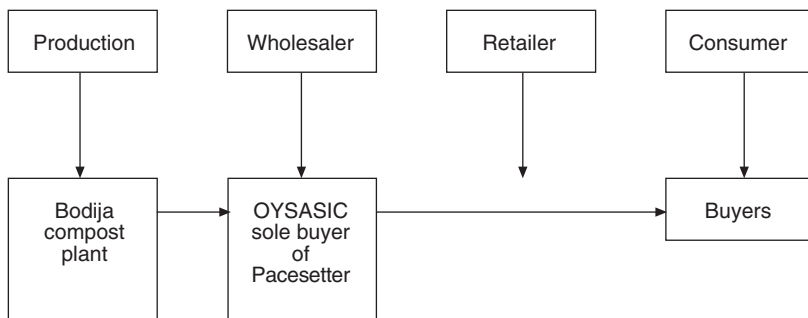


Fig. 3.1.4. The marketing chain.

Conclusions and Recommendations

The problem of solid waste recycling can no longer be treated lightly especially in view of its many inherent advantages, which are being tapped increasingly even by the developed nations of the world. As research into the various customers and uses of this fertilizer plant becomes more definitive in the future, all of the stakeholders stand to gain in the usage of waste as a means of livelihood.

Currently, the socio-economic impact of the project is not yet visible as the plant started operation in August 1998. Farmers using the compost should make the most significant gains. In addition, the plant employs people; firms have been appointed by OYSASIC to distribute the plant's products, which again cooperate with marketing and transport firms. Through these operations, many people hitherto unemployed have become employed.

The plant has made the plant machinery industry aware of the value and benefits of intellectual property rights. The designers of the plant's machinery have become experts as a result of the project. For example, Lagos state government, corporate organizations, and individuals have made contact on how to start such projects in their different localities. Project replicability in other markets in the city, as in Ayeye and in towns (e.g. Shomolu local government in Lagos), is desirable. However, the ownership and finance structure should be broadened to ensure management flexibility and especially, sustainability. Emphasis should focus on varying plant sizes for different communities but all with the same goals.

In order to derive maximum benefit from Bodija plant, it is recommended that all necessary facilities such as water and a standby generator be provided at the project site to ensure uninterrupted production. As soon as this is put in place, the proposed second production line should be effected.

Second, it is recommended that the marketing of the product be decentralized as proposed by the state government to popularize the use of the product and ensure that the benefits accruable from this project are diffused widely to all the inhabitants of the city region and Oyo State in general.

Third, a media campaign should be mounted, both in printed and electronic media, to inform more people about this type of fertilizer along with its inherent advantages over and above inorganic fertilizers.

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URBAN VEGETABLE PRODUCTION IN LAGOS AND IBADAN

M.A.O. Oladokun

Department of Horticulture, University of Agriculture, Abeokuta, Nigeria

With respect to urban agriculture in Nigeria, technology transfer is beleaguered by several factors among which are lack of definitive policy on urban agriculture, lack of adequate statistics on urban agriculture, heterogeneity of urban agriculture in terms of location, farming activities, state of development, etc., shortage of the right type of extension, as well as insufficient farm input distribution, procurement and supply.

A survey of vegetable farmers in the wetlands of Lagos and Ibadan showed that Lagos presents a better set of opportunities for urban agricultural development than Ibadan in terms of its availability of de facto and potentially cultivable wetland areas, accessibility by roads, easy produce disposal through marketing, as well as availability of farm services and regular visits by extension officers. The farmers are identified properly in terms of their location, crop production systems, population and distribution, requirements and problems. There are various vegetable production centres in the city that serve both citizens as well as hotels and tourist centres with, for example, Chinese spinach, okra, tomatoes, green pepper, lettuce, aubergine, spring onion, cucumber, cabbage, and many other vegetables.

In Ibadan there are lowland areas suitable for vegetable production as well as other farming activities. These include the banks of streams as well as isolated wetland areas that dot the city, which is enclosed by valleys and swamps. In terms of the availability and distribution of farm inputs, technology transfer, and types of vegetables cultivated, Ibadan has yet to meet the standard operating in Lagos. Vegetables produced in Ibadan include Chinese spinach, okra, aubergine, cucumber, and others. A significant fraction of these vegetables is passed to individual consumers through several local markets operating on a daily basis.

From the survey carried out in the two metropolises by Olaoye (1997), it was observed that about 73% of the interviewed 63 farmers make vegetable production a full-time business. Leasehold accounts for the dominant part of land tenure systems of urban vegetable production (Table 3.1.3). Farm sizes as well as the number of farm holdings by individual farmers are a factor of land tenure. In the present study, the preponderance of other forms of land tenure (82.5%) over that of inheritance (27.5%) makes it easy for farmers to increase both the number and the size of their farm holdings barring other determining constraints. This potentially paves the way for profitability, sustainability and expansion.

Table 3.1.4 shows that farm holdings in Lagos metropolis are larger than in Ibadan. This might be due to the larger size of wetlands suitable for urban agriculture in Lagos, and the higher vegetable demand encouraging farmers to increase the size and number of their farm holdings.

As inputs are expensive, vegetable farmers use different sources of capital (Table 3.1.5). With the removal of fertilizer subsidies in the country, most farmers now resort to the use of processed organic waste from compost compounding facilities, refuse dumps or land reclamation centres. In some cases when solid wastes are burnt in incinerators, resultant ashes and remains are used for vegetable production.

Table 3.1.3. Distribution of vegetable farmers according to land source in the two metropolises.

Land tenure	Lagos		Ibadan		Total	
	No.	Percentage	No.	Percentage	No.	Percentage
Owned	2	5	2	9	4	6
Inheritance	11	26	—	—	11	18
Leasehold	18	43	10	48	28	44
Rent	4	10	9	43	13	21
Gift	7	16	—	—	7	11
Total	42	100	21	100	63	100

Table 3.1.4. Distribution of vegetable farmers according to land size in Lagos and Ibadan.

Land size (ha)	Lagos		Ibadan		Total	
	No.	Percentage	No.	Percentage	No.	Percentage
< 1.0	7	17	14	67	21	33
1.1–2.0	12	28	4	19	16	25
2.1–3.0	5	12	0	0	5	8
3.1–4.0	8	19	2	9	10	16
> 4.0	10	24	1	5	11	18
Total	42	100	21	100	63	100

Table 3.1.5. Distribution of vegetable farmers according to capital sources in Lagos and Ibadan.

Source of capital	Lagos		Ibadan		Total	
	No.	Percentage	No.	Percentage	No.	Percentage
Bank loan	10	24	1	5	11	18
Private loan	2	5	—	—	2	3
Self	30	71	20	95	50	79
Total	42	100	21	100	63	100

3.2 Accra

TURNING MUNICIPAL WASTE INTO COMPOST: THE CASE OF ACCRA

I. Etuah-Jackson¹, W.P. Klaassen¹ and J.A. Awuye²

¹GROWTH Integrated Development Programmes (NGO), Accra, Ghana;

²Accra Metropolitan Assembly (AMA), Waste Management Department (WMD), Accra, Ghana

This chapter reports on solid waste management in Accra, Ghana, with a focus on experiences so far with two different approaches to urban waste composting. It also describes briefly the urban farming systems with reference to a study carried out by the Noguchi Memorial Institute in Accra.

Key words: West Africa, Ghana, municipal wastes, composts

Introduction

Accra, the capital of Ghana, has a population of approximately three million. Every day, an additional 500,000 people visit the city, and some 100 remain; a contribution to the rapid population increase in West African's urban centres.

With regard to the population increase and need for food security, the Accra Metropolitan Assembly (AMA) has recognized the value of food production in the city. AMA supports through the decentralization policy of the Government of Ghana the institutionalization of urban and peri-urban agriculture through a related Department and Sub-Committee in the Assembly. Every year at the 'National Farmers Day' the official recognition is expressed in awards for the best urban and peri-urban farmers per city¹.

¹Besides best district, regional and national farmers.

But Accra is not only a pacesetter with regard to urban agriculture. AMA has also pioneered the composting of urban waste in West Africa with the establishment of a huge compost plant 20 years ago. This chapter focuses on lessons learnt from this and other compost production approaches in Accra, and briefly describes the current and potential users of the compost.

Generation, Collection and Disposal of Solid Waste

According to official figures, the total quantity of waste generated in Accra from households can be estimated at approximately $840,000 \text{ m}^3 \text{ year}^{-1}$. This waste can be categorized into two main types, solid waste and liquid waste. In 1998, solid waste generated was estimated at approximately $765,000 \text{ m}^3$ while the figure was 75,000 for liquid waste. The AMA Waste Management Department (WMD) is responsible for the management of both kinds of waste. Official disposal points are in Teshie-Nungua (with a compost plant) and Malam (only a landfill site). Faecal sludge-treatment sites exist in Teshie-Nungua and in Achimota.

The total quantity of solid waste collected in the same year in Accra was $669,000 \text{ m}^3$, implying that about $96,000 \text{ m}^3$ of waste was not collected. Other sources give higher figures. This waste will most probably have been disposed of illegally, i.e. at unofficial sites. Improper handling and disposal of this waste poses a major hazard to the environment and its inhabitants. Rivers in Accra are polluted (cf. Mensah *et al.*, Chapter 2.3 this volume) and there is a need for proper disposal of liquid and solid waste to avoid future health hazards to the population.

As the WMD could not provide quality services due to inadequate logistics combined with administrative problems, AMA contracted waste collection out to private collectors. Each of the contractors had been assigned to a coverage area. The total solid waste collected by private contractors in 1998 was $247,528 \text{ m}^3$ or about one-third of the total waste collection. In 2000/2001 a complete coverage was expected.

Waste Collection Services in Accra

House-to-house collection

High-/medium-income and low-density areas only demand this waste collection service. Areas such as Labone, Roman Ridge, Tesano, Cantonments and Airport Residential Area are some of the beneficiaries. At the moment customers pay between ₵14,000 and ₵20,000 monthly per house². The annual collection of solid waste in these areas for 1998 totalled $66,899 \text{ m}^3$ and this

²US\$1.00 = c. 2600 cedis (1999).

forms approximately 10% of the year's total solid waste collection. Compaction trucks are used for the house-to-house service.

The private collectors who operate mostly in the middle and lower income areas collect 37% of the total solid waste collected in Accra. This amounts to approximately 247,528 m³. A fee ranging between ₵12,000 and ₵18,000 is charged per house month⁻¹.

Collection in central containers

Low-income and high-density areas, where households cannot afford individual collection, have been considered by the WMD which places central containers at strategic points. These containers are monitored and supervised by the various sub-metro offices, and they also ensure that the containers are emptied when full. Multi-lift trucks are used for the central container service. At the moment no fee is charged for the dumping of refuse into the central containers. In 1998, the central containers were used to collect 45% of the total solid waste collected in the year, which amounted to 301,048 m³.

Special collection cases

In 1998, special waste from commercial houses, private companies, markets, car parks, government institutions, and diplomatic missions, was collected with a volume of 33,450 m³ (5%).

Some non-governmental organizations (NGOs) and community-based organizations (CBOs) operate waste collection services in specific communities within the AMA. These services are predominantly via small tractors and push-trucks. These NGOs/CBOs are precollectors, or try to recycle the waste collected. An example of a CBO involved in waste collection in Accra is the Ashiedu Keteke Community Participation Project (AKCPP) in Ussher Town. In the low-income area, the fee for collection of household waste per month per household ranges between ₵2000 and ₵6000. The total solid waste collected by NGOs/CBOs in 1998 was approximately 6690 m³ or 1% of the overall waste collected in Accra this year.

Another example is the 'Kaya Bola Boys', several self-employed youths who collect waste from individuals in low-income areas with the aid of push carts, for a small fee, and dump the solid waste mostly at unofficial places such as beaches. The solid waste collection by the Kaya Bola Boys can be estimated at 13,380 m³ year⁻¹ (2% of total solid waste collected) (Lamprey and Abban, 1999).

Finally, in autumn 2000 the City Waste Management Company Ltd started a plastic waste recycling plant at Afoaman, Pokuase, at the boundary of the metropolitan area. The plant has a minimum capacity of 45 t of plastic a month. In collaboration with the NGO 'Hope for Life' the company intends to put up kiosks at 10 central locations to cover the entire metropolis of Accra,

where scavengers and users will be encouraged to send plastics for a token amount (Van-Ess, 2000).

Solid waste disposal and composition

A survey of the composition of waste revealed that the organic waste fraction formed the highest part of the total solid waste generated in Accra. The average percentage is 55.5%. Another important fraction was the inert component (soil) with an average percentage of 33.5%. This value was recorded because of the daily sweeping of compounds (houses). The paper fraction (3.9%) was collected mainly in areas with some business activities. All other six fractions (plastic, glass, metals, textiles and others) contributed only a small quantity each to the total waste composition (Table 3.2.1).

The data show that waste in Accra has a good potential for composting activities, due to the high percentage of organic matter. The organic component of the waste in low-income areas is far less than in the middle- and high-income areas, where the inert component is far higher than in the medium- and high-income areas; this is due to the fact that the compounds in such areas are swept every morning and sand is collected and dumped in the waste containers. As expected, the percentage of glass, plastic and metal in the waste from low-income areas is less than from the medium- and higher income areas. Other waste components like batteries, thermometers, medical drugs and hazardous residues are also found less often in the waste of the lower income areas.

Other sources of solid waste

Organic waste can also be obtained as agro-industrial by-products from large poultry farms, breweries, slaughterhouses, juice factories, etc. Gerner *et al.*

Table 3.2.1. Solid waste composition in Accra (percentages).

Waste composition	Low-income areas	Medium-income areas	High-income areas	General
Organic	49.1	73.0	72.6	55.3
Inert	41.2	12.1	8.9	33.5
Plastic	2.7	3.0	4.0	2.8
Glass	0.4	1.2	2.0	0.6
Paper	3.5	6.0	7.2	4.2
Metal	0.7	1.7	2.8	1.0
Textile	2.1	2.4	1.5	2.2
Others	0.3	0.6	0.9	0.4

Source: AMA/WMD data from 1993.

(1995) and Owusu-Bennoah and Visker (1994) give an overview about the different organic by-products available in Accra. Some of these products have a high fertilizer value but are also used for other purposes, such as fodder or for soap production.

Compost Production from Waste in Accra

Presently there are two compost plants or compost production sites in Accra, a large plant at Teshie-Nungua (operated by the WMD of AMA) and a second smaller plant at the timber market in the Ashiedu Keteke sub-district of Accra (operated by the AKCPP). In addition, some individuals have started to produce/collect composted waste from unofficial dumping places; some sell it to horticulturists.

The Teshie Compost Plant

The composting plant at Teshie-Nungua, in the Kpeshie sub-district in the AMA, was established in 1979 and started production in 1980. The purpose of the plant was to serve as a disposal site for the city of Accra and to process solid waste rich in organic matter into organic fertilizer for peri-urban use. The main advantages of the plant are proximity to collection sites and the large volume of compost production. The plant operates with a minimum of manpower, and is capital intensive. Theoretically, it can produce about 20 t h⁻¹, which is approximately 38,000 t annually. For various reasons, such as lack of electricity, water, and technical problems, it has worked only occasionally and gradually become a near total disposal site. Table 3.2.2 shows compost production at Teshie in recent years.

The compost plant, which had originally no settlement in its vicinity, is now within the developed Teshie-Nungua community which complains about the odour of non-composted waste.

The plant has a site for composting solid household waste as well as a site for night-soil sewage treatment. Both come from Accra East (La, Teshie, Nungua and parts of Osu) and are transported to the compost plant from a radius

Table 3.2.2. Compost production of the Teshie-Nungua Plant 1994–1997.

Year	Production in t
1994	495
1995	3506
1996	1605
1997	915

Source: AMA/WMD.

of 10 km. Because of the long storage period, much of the solid household waste has turned into compost by itself and mainly needs to be separated and sieved. The night-soil is settled through a number of basins. At the end of the chain the dried sludge is mixed into waste at a ratio of 1:4 (night-soil to solid waste).

For the composting process, it was originally planned that daily solid and liquid wastes are treated at the compost plant by weighing and dumping the waste into windrow piles for 4 weeks together with sludge from the treatment plant mixed with sawdust. Moisture content is about 55%; the initial temperature about 50°C. After the first 3 months, the temperature rises to about 70°C. The moisture content, which drops during the decomposition period, is taken care of by spraying the treated liquid waste, which is rich in nitrate, from the treatment plant on to the windrow piles, instead of allowing the treated waste to flow into water bodies. The windrow pile is turned four times within 12 months. After this period the temperature drops to about 30°C and the moisture content to about 20%; hence it is a safe product. Table 3.2.3 presents results of compost analyses.

However, the malfunction of the turning machine (payloader) made the whole system ineffective; windrow piles cannot be oxidized by turning and the plant cannot be loaded for production. Therefore waste remains at a disposal

Table 3.2.3. Compost analysis of the Teshie-Nungua compost plant and data from 33 municipal composts from UK composting sites for comparison.

Elements	Unit	Teshie	Range (UK)	Median (UK)
pH		6.8–8.5	7.4–9.0	8.5
EC	$\mu\text{S cm}^{-1}$	700–1960	182–2800	885
Ammonium (1:6 water extract)	mg l^{-1}	2–3	1–299	9
Nitrate (1:6 water extract)	mg l^{-1}	314–682	0–1057	97
Phosphate (1:6 water extract)	mg l^{-1}	23–449	5–296	17.5
Potassium (1:6 water extract)	mg l^{-1}	707–2020	171–3770	1442
Magnesium (1:6 water extract)	mg l^{-1}	67–752	5–242	20
Nitrogen (total)	%	0.45–1.3	0.55–2.57	1.15
Phosphorus (total)	%	0.28–2.21	0.1–4.14	0.22
Potassium (total)	%	0.34–0.35	0.21–1.67	0.78
Carbon (total)	%	3.02–12.3	6–31.7	12.8
Loss on ignition	%	5–23	9–61	21
C:N		7–15	5–21	11
Cd (total)	mg kg^{-1}	0.3–1.0	0.2–4.15	0.49
Cr (total)	mg kg^{-1}	22–54	10.9–123	18.6
Cu (total)	mg kg^{-1}	22–272	20–81.7	40.05
Pb (total)	mg kg^{-1}	64–201	37.2–200	95.7
Hg (total)	mg kg^{-1}	0.34–0.78	0.05–0.33	0.12
Ni (total)	mg kg^{-1}	11.2–15.7	9.2–69.8	17.95
Zn (total)	mg kg^{-1}	165–837	84–609	192.5
Dry matter	%	65.2–87.0	28–79.9	67.5
<i>Salmonella</i>	25 g^{-1}	absent	1–7800	240
<i>E. coli</i>	CFU g^{-1}	< 10	0	0

site and is later forwarded for production while the treated sewage effluent flows through a drain leading through the community into the sea about 5 km away from the plant. Currently, a new sieving drum and conveyor belts have been installed, allowing the plant to run at least on a reduced basis, because the demand for compost is increasing especially from real estate developers.

The economic problem is that the plant is only a profitable venture if it is operated and maintained well. In all other cases, it becomes a cost-intensive experiment. Assuming ideal operation of the plant for 5.5 days a week for 52 weeks a year the following cost–benefit estimates (in million cedis³) were obtained:

Electricity charge	17
Fuel	32
Water	5
Spares and consumables	60
Labour	22
Total	<u>136</u>
Annual revenue of compost	156
Annual disposal charge	43
Total	<u>199</u>
Revenue	<u>63</u>

Other disadvantages of the plant are:

- Distance to compost users is slowly increasing as the city grows.
- Authorities' priority still concentrates on the collection of solid waste thus the plant did not receive the necessary financial commitment to maintain its function.
- Presence of heavy metal will need waste separation (at source) in future.
- Breakdown of the plant results in environmental impact through waste accumulation.

The AKCPP Compost Plant

The AKCPP compost plant, which is operated manually, has been in operation since 1997 and produces compost of similar quality as the Teshie plant as analyses show.

The waste collected from households is heaped and watered. Scavengers are used to sort out metal pieces from the heap, but this is not done systematically. After 3 months the waste is turned and watered manually and covered with treated night-soil from the sewage treatment plant to avoid flies. The inner

³US\$1.00 = c. 1700 cedis (1996).

temperature of such heaps reaches 70°C and above. Measurements of temperature are taken regularly to avoid health risks by incomplete composting. After another 3 months the waste is turned and watered and covered with treated night-soil again. It takes another 3 months for the final decomposition. After 9 months the compost is almost ready, and enriched with settled sludge from the Achimota treatment plant by 50%. It is then sieved in a sieving drum that is operated by an electric motor. The size of the compost particles does not exceed 10 mm, which is a sign of very good quality.

The compost is heaped until it can be sold in either plastic sacks of 50 kg or in 7 m³ containers. Usually the compost can be sold in the 3 months following production. In 1998, the amount of compost produced by the AKCPP was approximately 150 t. At the end of 1998, the compost plant had four workers and one supervisor.

The compost has been sold by the WMD/AMA since the initiation of the project. Marketing of the compost has to be improved since compost to the value of approximately ₡6 million lies at the plant site unsold. This was generated during the dry season, when demand was low. *GROWTH* Integrated Development Programmes are looking into the possibility of packing the compost in smaller bags of 25 kg or 10 kg for easy handling. A study is in progress.

The selling price of one sack of compost (50 kg) is ₡5000⁴. The container price for 7 m³ is ₡160,000; additional transport cost will be charged. However, the compost plant managed by the AKCPP is only 'profitable' through the sale of sacks of compost to horticulturists and private persons. This is far more profitable than selling compost in containers. One container contains 140 sacks of compost, this gives an average price of $140 \times ₡5000 = ₡700,000$ per container. Currently, many customers of the compost plant are not farmers but gardeners from high-income areas, such as embassies. Urban farmers interested in the product are mostly vegetable producers (cf. Box 3.2.1), however, many of them dig composted waste ('black soil') at illegal waste dumps for free.

Without the collective effort of the AKCPP group working on voluntary basis, the assistance of Ashiedu Keteke sub-district (which gave the land for the plant), the WMD/AMA (which sells the sacks of compost for the AKCPP), and the help of a private company which brings night-soil from Achimota to the compost plant (the AKCPP pays for the fuel), the compost plant would not be in existence by now. People identify themselves with the small compost plant, so it is part of awareness raising in the area; it is also likely that the waste will be regarded as something that has value.

Even though the content of inorganic matter in waste such as plastic, glass, and metal is quite low, additional income is generated by separating them, especially glass and metals, more systematically for recycling purposes such as glass for *terrazzo* and bead production and metals for smelting. Plastic recycling will be possible in the new plant in Pokuase (see above). This additional recycling is necessary to make the plant economically viable.

⁴US\$1.00 = approximately 2600 cedis (August 1999).

Box 3.2.1. Farming systems in and around Accra, Ghana.

As a result of growing concerns regarding increasing poverty in Accra, a study on livelihoods, food and nutrition security in the Greater Accra Metropolitan area was undertaken by the Noguchi Memorial Institute for Medical Research and the International Food Policy Research Institute in 1997. Specific questions addressed included a descriptive analysis of the geographic, demographic and socio-economic distribution of urban agriculture in Accra, the impact of urban agriculture on livelihood, food, and nutrition security at the household and individual level, and the effect of the rapid growth of the city on changing land use, property rights, and livelihoods on the peri-urban fringe.

Methodology: The quantitative part of the study involved a survey of 559 households from 16 randomly selected enumeration areas in Greater Accra, comprising Accra and Tema and parts of the (peri-urban) Ga District. The qualitative part of the survey involved in-depth case studies and focus group discussions with various farmers and farming groups in the identified farming categories to investigate the impact of their activities on income and household food security.

Results and conclusions: Findings indicate that food crop farming was the major agricultural activity in Accra. Among livestock keepers, poultry husbandry was the most common. Overall, seven categories of farming systems were identified:

- *Seasonal crop farming:* rainfed, seasonal agriculture, relying mostly on informal land access and mostly produced for home consumption.
- *Customary land rights system:* rainfed agriculture with some dry season irrigation on La 'stool-land' between La and Teshie for both home consumption and marketing.
- *Vegetable growing system:* irrigated market-oriented production of vegetables, mostly relying on informal land access and usually carried out along main drains and streams.
- *Small ruminants and poultry:* raising small livestock in densely populated areas sometimes market oriented but more frequently as an investment or asset strategy.
- *Backyard gardening:* small-scale gardening on individual's land or rented compounds, usually for home consumption.
- *Commercial livestock:* usually poultry, pigs, goats, sheep and cattle raised at medium to large scale for sale to urban markets.
- *Miscellaneous:* export crop production, micro livestock, snail farming, bee keeping, large ruminants.

Out of 559 households in the 16 enumeration areas, a total of 88 reported a member engaged in some form of agriculture, and 11 reported fishing as a livelihood. Of those engaged in agriculture (including livestock keeping), 12 farmed in their home villages, which were well outside the city, and therefore outside the study area. That left 76 households (14%) out of the total sample,

Box 3.2.1. Continued

engaged in agriculture in the Greater Accra Area. This figure is comparatively low (cf. Nsiah-Gyabaah and Adam, Chapter 3.3 this volume). However, since the statistical database of the peri-urban sector is very small, it is likely that the number of people farming in the peri-urban area is much higher. It is also likely that more households have some kind of small backyard, however, they did not consider this worth mentioning as 'agriculture'.

Farming is fairly evenly spread across income groups. In most cases, farming was a secondary or tertiary activity except for the vegetable growers and peri-urban farmers. Much of the farming activity in the city is on individually or household owned land, though a considerable amount of farming was found on informally accessed land. Use of poultry manure, cow dung, and organic waste as manure was popular especially among vegetable growers. Fertilizer and pesticide use was popular among the customary land rights group possibly due to their contact with extension services.

The main constraints mentioned by farmers for land were: both physical access and tenure security; high cost of farm inputs; theft of crops grown far from the household; marketing, both physical space for the activity and the necessary organizational arrangements to permit and promote direct farmer-consumer marketing; and the use of polluted water for irrigation from the drains and streams that flow through the city.

There are a number of farmers' associations in the city, including a Vegetable Grower's Association and a Commercial Poultry Farmers' Association. Institutional support from municipal and local government exists in the form of extension services; several NGOs have experience in urban agriculture programmes.

Reference: Armar-Klemesu, M. and Maxwell, D. (eds) 1998. *Urban Agriculture in the Greater Accra Metropolitan Area*. Final Report to IDRC. Noguchi Memorial Institute for Medical Research, University of Ghana.

Conclusions

1. From the positive point of view, compost production on a small or large scale:

- Reduces household waste that goes to the landfill site (large scale > small scale).
- Reduces environmental pollution (large scale >> small scale).
- Provides job opportunities, e.g. for the unemployed youth (small scale > large scale).
- Upgrades farmland by using compost for crop farming and gardening (small and large scale).
- Has proximity to collectors and users (small scale is easy to multiply or translocate).
- Has low sensitivity to technical problems (small scale).

2. In comparison with mineral fertilizer, compost has an additional value of improving the soil structure. Thus compost in the long term will be more advantageous to the farmer. But some difficulties related to selling the compost to the farmer have to be taken into account:

- The large quantity that is needed on farms. For some crops, this is estimated at 20–30 t ha⁻¹ or more.
- The price of compost depends largely on transport costs, thus it can become far higher compared with inorganic fertilizer with increasing distance from the plant.
- The application of compost demands more manpower and it is therefore more expensive.
- Little information and support from extension officers makes it difficult to interest the farmer in the use of compost.
- Interrupted or insufficient supply will be a constraint; supply must be regular.
- Quality monitoring (especially in view of contamination) needs more attention.

3. The following steps should be taken to improve the marketing of compost:

- Extensive education of students and adults in the peri-urban areas through schools and community fora.
- Education of extension officers and farmers on the positive effects of compost; reduction of possible prejudices against the mixture of waste and night-soil.
- Establish model/demonstration farms and gardens in farming areas in cooperation with the private sector.
- Using farmers' associations to buy compost in bulk, to reduce transport costs.
- Combining compost use and integrated pest management to show multiple advantages (see Kessler and Helbig, Chapter 3.5 this volume).

In summary, the Accra example shows that largely mechanized compost plants need high levels of support and input, which are difficult to maintain in most public institutions. Therefore, it appears to be more realistic to focus on labour-intensive small- or medium-scale compost stations in the urban- and peri-urban context. To make such stations economically viable the additional recycling of metal, glass or plastic should be taken into consideration as well as the integrated pest management potential of waste compost.

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3.3 Kumasi

FARMING SYSTEMS AND FARMING INPUTS IN AND AROUND KUMASI

K. Nsiah-Gyabaah¹ and M. Adam²

¹ Sunyani Polytechnic, Sunyani, Ghana; ² Natural Resources Institute (NRI),
Chatham Maritime, Kent, UK

This chapter examines the farming systems in and around Kumasi and the impact of urbanization and rapid population growth on natural resources and the environment. The use of inputs in the farming systems is described and it is shown that large quantities of potentially useful organic fertilizer material are wasted. Some general recommendations for future activities to improve the situation are put forward.

Key words: West Africa, Ghana, farming systems, urban agriculture, live-stock, bush fallowing, nutrients

Background

In the past few years, much attention has been focused on issues pertaining to sustainable agricultural development and natural resources management in peri-urban Kumasi because of accelerated degradation of the resource base. The impact of urbanization and population growth on the natural resource base and the environment has not only undermined local food security, but it has forced many women out of agriculture.

It is estimated that by the beginning of this century, more than half of the world's 5 billion people will be living in towns and cities, and more than 80% will live in what is today called the 'developing world'. The challenge that this growth presents to decision-makers and planners in meeting the growing needs of food and shelter is complex.

In Ghana, rapid population growth, social change, rural to urban migration and uncontrolled urban expansion have affected the sustainability of

farming systems and the environment greatly. Farmers have faced the challenge of adapting their farming systems to these constantly changing conditions in areas where they are constrained by tenancy, rapid population growth, urban encroachment on farmlands, and other pressures.

In 1995, a baseline survey in Kumasi identified serious constraints to agriculture and management of peri-urban natural resources. It was observed that the nature of urban growth and the ways in which it impinges on natural resources, farming systems, and the environment had not been analysed adequately and, consequently, not well understood.

The Kumasi Natural Resources Management Project (KNRMP) was, therefore, initiated with funding from the Department for International Development to:

- examine farming systems, planning processes and resource management in peri-urban Kumasi;
- develop practical strategies to improve natural resource management and increase agricultural productivity;
- strengthen local capacities and improve planning processes; and
- improve access to and use of geo-referenced data relating to natural resource management in peri-urban Kumasi.

Methodology

The chapter draws on results from four project components:

1. A participatory rural appraisal (PRA) study of six peri-urban communities.
2. A socio-economic (questionnaire) survey of 67 peri-urban settlements—village characterization survey (VCS).
3. Sample surveys of urban natural resource use.
4. A survey of supply of and demand for soil ameliorants in urban and peri-urban Kumasi.

An important component of the study was an analysis of changes in farming systems as a result of urbanization and increasing population growth. The main characteristics of the farming systems are outlined below.

Results

Farming systems – peri-urban

Agriculture is the basic sector of the economy on which the majority (about 70%) of the people depend for their livelihoods (NRI, 1996). In the Ghanaian context, farming has evolved from indigenous shifting cultivation and its offshoot, bush fallow with land rotation, to permanent inter-cropping and intensive valley bottom vegetable cultivation.

The farming systems and cropping of indigenous and exotic species and local adaptations have implications for the environment and biological diversity. Under the relatively low population pressure prevailing in the past, shifting cultivation and bush fallow were sustainable because they provided the advantages of:

- minimizing soil erosion;
- preserving agro-diversity; and
- maintaining ecological stability.

These indigenous farming systems included farmers' choices of crops and animals, agroforestry, management of biodiversity within them, and management of land, water and various other living and non-living components of the resource base (Brookfield, 1994; Brookfield and Padoch, 1994).

Such time-tested indigenous land management systems also included intensive kitchen and home gardens and compound farming. These are inherently self-regenerative and protective of the soils and biological diversity, because of their close adaptation to the natural biophysical environment and minimal dependence upon artificial external inputs.

This cultural adaptation derives from the small traditional farmers' intimate understanding of the agro-environment as a delicately structured ecosystem whose sustainability depends upon minimal disturbance. Thus, the indigenous farming systems were sustainable under low population pressures.

However, urbanization and pressure of population have undermined the sustainability of the indigenous farming systems, leading to accelerated land degradation and declining crop yields. With increasing population pressure and land shortage, the indigenous farming systems have given way to more intensive systems, characteristics of which include:

- small farms, with over 90% below 2 ha;
- shift from large-scale plantations to food crop production for home consumption;
- cultivation of early-maturing crops and varieties that are more efficient in the utilization of water and minerals;
- market gardening and production of valley-bottom vegetables for sale;
- livestock or animal rearing especially poultry;
- reduction in fallow periods from 3 years to 1 year or completely eliminated in many places.

Currently, the farming systems in peri-urban Kumasi consist of varying mixes of traditional and introduced elements. These include:

- temporary intercropped bush fallow food crop, rainfed (women predominantly);
- permanent intercropping;
- monocrop vegetables, with irrigation in the dry season;

- specialized valley-bottom cropping, e.g. sugarcane, taro, green maize (men predominantly);
- tree crops;
- backyard farms (mostly banana, plantain, cassava and vegetables);
- livestock (little integration with crop farming); and
- fish farming.

Bush fallow food crop

The bush fallow relies on naturally occurring biological processes to control pests and the intermixture of species to sustain agro-ecological stability and optimum use of soil nutrients. It uses crop rotations that mitigate weed, disease, insect and other pest problems, reduces soil erosion and maintains soil nutrient levels, thus reducing the need for fertilizers. This enables food security and provides a balanced diet.

This farming system is based on maize, cassava and plantain cultivation with various degrees of interplanting of cocoyam, groundnut, beans, garden eggs (aubergine), tomatoes, leaf vegetables and peppers. Cassava and maize are the dominant crops. The local maize varieties take 4 months to mature. They are planted once the main rains are considered reliable (February–April). Maize is planted on soils with better water-holding capacity. Usually the deeper soils of the lower slopes of the valley sides are planted earlier in the season. After about 1.0–1.5 months, cassava is interplanted in the maize. The cassava varieties used vary in their maturation period (13 months to 2 years). While some farms plant a single variety, others deliberately mix cassava of differing characteristics. The density of plantains varies greatly, and in some fields they are grown as the main crop.

Fire is a common feature of the bush fallow farming system. It is an important tool for clearing the land. Cutlasses and fire are employed to eliminate trees and other weedy cover, which leads to the dominance of grasses and, increasingly, the obnoxious Acheampong weed, (*Chromolaena odorata*). Agriculturalists and environmental groups consider burning to be a detrimental practice that reduces long-term soil fertility, exposes the soil to erosion and can increase weed invasion, for example by spear grass (*Imperata cylindrica*). Of the villages surveyed in the VCS 76% said that this weed had increased greatly in the last 10 years. But the majority of farmers believe that burning is a beneficial practice. Fire is seen to have several advantages including the addition of potash that brings ‘strength’ to the soil and the ability to combat harmful organisms that affect crops.

Both men and women operate food-crop farms. However, in several villages where urbanization is increasingly replacing farming as the main land use, it is usually the women who continue to maintain food-crop farms. Women’s farms tend to exhibit a much wider range of interplanted crops for both commercial and domestic use. In most places, men’s farms tend towards simpler maize, cassava and plantain systems.

Permanent intercropping

This is the end result of the ultimate decline in the fallow period to zero. Without use soil ameliorants, farming in this way is no more than short-term soil mining. The practice is, nevertheless, increasingly found to occur in peri-urban villages.

Monocrop vegetables

This system is based on the commercial production of intensively-produced, irrigated horticultural crops including tomatoes, cabbage, lettuce, onions, carrots and occasionally garden eggs (aubergines).

Most frequently, valley-bottom vegetable farming is carried out by the youth. It is both physically arduous and time consuming, e.g. raising beds and ridges above the high water-table levels and subsequent twice-daily watering. It demands some access to capital (or credit) for the purchase of seeds, fertilizers (including poultry manure) and pesticides that are intensively, but not always correctly used.

Misuse of chemicals intended for cocoa on vegetable crops is said to be common as these products are subsidized heavily and may sell at less than a quarter the price of the recommended horticultural products. Even though no data exist, it is clear that the practice of high-input horticulture in close proximity to streams is bound to result in watercourse contamination. Some young men, aware of this, use biological control of caterpillars on cabbage.

Although this is potentially the most profitable form of agriculture (per unit area), it does entail some risk of crop failure from pests and diseases or of local and short-term market over-supply at the time of harvest. Many of the young men are not resident in the areas that they farm, but actively look for land close to dry season watercourses within the peri-urban area.

Specialized valley bottom farms

These are based on taro-yam (*Colocasia* sp.) or sugarcane, and may include areas of traditional vegetables, e.g. garden eggs, tomatoes and leafy vegetables, which are important in the dry season, often occupying fairly swampy land that floods in the rains. These farms are usually associated with men. Crops with less tolerance to poor drainage are often grown on mounds or ridges. Vegetable and short-season maize (for fresh maize consumption which commands high prices early in the season) is planted in this way or at the margin of the swampy land.

Taro-yam, with its tolerance to flooding and relatively low labour inputs, is a very important component of valley-bottom farms, notwithstanding its historical reputation as a poor man's food. This is particularly the case in the more urban, land-constrained villages. Indeed, a considerable area of taro-yam is evident in the intra-urban seasonally flooded valley bottoms. Whatever the public health considerations, heavy organic pollution of some peri-urban streams favours the growth of taro-yam.

In many villages seasonally-flooded land is being allocated for housing sites (with or without appropriate drainage works). Many valley-bottom farmers are cultivating opportunistically on such land until building work starts.

Tree crop farms

Cocoa and oil palm were important components of agriculture and land use in the past. However, only a few remnant cocoa farms and some oil palm (mostly wild types and some hybrid trees) intercropped with food crops remain today. Some peri-urban farmers grow both cocoa and oil palm in areas distant from Kumasi, especially Brong Ahafo and the Western regions. This is because of growing land scarcity in the peri-urban area, coupled with the prevalence of cocoa diseases and, according to the farmers, changes towards a climate with more prolonged periods of dry weather.

Oil palm and coconuts on roadsides or field boundaries and mixed fruit tree cultivation (usually in backyard gardens or in fields close to the house) are visible in all the villages. Women see these as important both for domestic consumption and for sale in the local markets or Kumasi.

Backyard farms

Backyard farming in the settlements closest to the city centre is growing in importance. The backyard farms are small plots adjacent to the house. They are particularly characteristic of the more urbanized villages where substantial new development has taken place. The new villas and older government houses that have large plot sizes provide sufficient space for their owners to plant a variety of crops.

Relatively high long-term investment is involved in some of these plots – e.g. in the planting of fruit trees. A wide mixture of crops is grown including the main staples – plantain, cassava and cocoyam – and vegetables. The primary purpose of these farms is for home consumption, but surplus may be sold.

Livestock

In the peri-urban area the characteristic livestock farming system is intensive or semi-intensive poultry production. Out of 20 villages selected at random in the peri-urban area for a special survey, only one did not have a poultry farm, and the others had an average of two farms. Keeping of poultry has increased significantly in the last decade and is dominated by men. It is possible that the high capital and labour requirements for entry into poultry keeping result in woman's lack of interest in the enterprise. Further research is required to understand the attitude of women to poultry farming.

Sheep, goats, cattle and pigs are also kept in the peri-urban area but are of less significance than poultry (Table 3.3.1).

Table 3.3.1. Number of villages (out of 66) in which certain proportions of villagers keep different livestock types.

	Proportion of villagers keeping livestock				
	None	Some	About half	Most	Almost all
Sheep	5	33	23	5	0
Goats	32	21	11	2	0
Pigs	51	15	0	0	0
Cattle	46	20	0	0	0

Source: Kindness (1999).

Fish farming

Fish farming is carried out but it is not popular and only a few male farmers are engaged in the activity. It appears that most producers entered into fish farming as an income-generating activity, but most have been so unsuccessful that it has become a subsistence activity.

Farming systems – urban

Studies of farming systems in the Kumasi Metropolitan Assembly district area – taken to include all the urban zone – are ongoing. There is no reason to suppose that all the farming systems present in the peri-urban area are also found in the urban area, though the amount of bush fallow as opposed to permanent inter-cropping may be limited.

Students of Kwame Nkrumah University of Science and Technology in Kumasi completed studies into eight production systems found within the urban area. These are:

1. Cattle production;
2. Sheep and goat production;
3. Pig production;
4. Poultry production;
5. Small animal (e.g. grasscutters (agoutis), snails and bees) production;
6. Aquaculture (fish farming);
7. Backyard crop production; and
8. Fuelwood gathering and use.

The studies show that the socio-economic characteristics of the urban natural resource managers (owners, farmers and gatherers) vary considerably with the type of natural resource. The extremes can be seen in the poor fuelwood gatherers who have little or no capital to outlay and consequently have low returns, yet are often entirely dependent on the activity for their livelihoods; and the rich large-scale poultry farmers and some of the cattle owners, who may invest significant capital and reap high returns, but for whom the activity is secondary to an established off-farm business or occupation. For others, for

example many of the backyard crop producers, the activity is stated by them to be at least partly a hobby.

The preponderance of traditional rainfed food crops – plantains, cassava and cocoyams – in backyard gardens was a strong feature of the urban as well as the peri-urban area (Table 3.3.2).

Many households grew tree crops (mango, pawpaw and avocado) as vegetables. Also, many households had one or more oil-palms. There were, rather surprisingly, few notable differences in the cropping patterns between plots in the higher- and lower-class housing areas, except that sugarcane and the local ‘apple’ (*bodu*), was more widely grown in the medium- and low-class areas. Perhaps the most striking feature, given the high housing density of some of the areas studied, was that on *all* plots surveyed there was some form of food crop cultivation taking place. If ‘gardening’ is synonymous with food crop production, then Kumasi is still the ‘garden city’ it was once envisaged to be (Korboe and Tiple, 1995).

Cattle, sheep, goats and pigs kept within the metropolis tend to be concentrated in certain areas and associated with particular ethnic groups. Cattle, sheep, and goats are held mostly by northern Ghanaians and pigs by Akan (Ashanti, Fanti, Kwahu) tribes.

Use of inputs in farming systems

Externally-sourced agricultural inputs to the traditional bush fallow farming system are minimal. Chemical fertilizers and pesticides are used rarely, and

Table 3.3.2. Percentage of houses having crops in backyard gardens.

Crop	Percentage of houses
Plantain	90.0
Cassava	44.4
Cocoyam	34.4
Taro-yam	17.8
Maize	11.1
Yam	5.6
Sugarcane	11.1
Vegetables	35.6
Oil palm	44.4
Mango	38.9
Papaya	35.6
Avocado	27.8
Orange	22.2
Coconut	18.9
Local apple	16.7
Guava	12.2
Cocoa	8.9

Source: KNRMP (1999).

little organic manure is applied. Traditionally, fertility has been maintained by the fallow period but, in situations of land shortage, this has either been eliminated or reduced to the extent where it is too short. The present situation is that the use of inputs other than labour is dominated by those external to the natural resources of the area (Table 3.3.3).

The chemical fertilizers most commonly used are compound 15:15:15 and ammonium sulphate, mainly applied to vegetables. This is in agreement with findings in Ghana by Harris (1997). Thus, there is little effect on the seriously low phosphorus status and strong acidity of many of the upland soils, because monocrop vegetables are grown generally on valley-bottom and lower slope soils. However, some chemical fertilizer is applied to upland cereal crops in the more intensive cereal monocrop systems found typically in some of the more distant peri-urban villages. It was noted in several villages that inorganic fertilizer was perceived as spoiling the quality of the traditional staple dish (*fufu*) made from cassava, to which it had been applied. However, there does not appear to be a common awareness among farmers of the differing effects of inorganic and organic materials on soil properties.

Farmers are aware of the problems of declining soil fertility. Also, they complain of the increase in bush fires, which interfere with the process of organic matter accumulation which the fallows provide. The soil analyses, carried out as part of the VCS, highlighted the actual and potential loss of organic matter from the soil. It is notable that there is little use of manures for improving the organic matter status, although the use of poultry manure is regarded as a major farming innovation of recent years. Reasons suggested by the farmers themselves for the generally low use of organic manures are: lack of availability, the extra cost of labour involved in transport and, though less often, lack of appreciation of the benefits of use. Harris (1997) encountered a similar set of reasons in his survey in Ghana, with the addition of a small minority of farmers who mentioned the social unacceptability of manure use.

While demand for organic manures would appear to be low, but increasing, supply would appear to be abundant though concentrated at points of

Table 3.3.3. Input use in 66 peri-urban villages.

Input	Number of villages where at least some farmers use the input
Chemical fertilizer	61
Insecticides	57
Fungicides	43
Weedicides	38
Poultry manure	17
Compost	2
Sheep manure	1
Cattle manure	1

Source: Village characterization survey (VCS).

origin. Poultry manure is dumped and sometimes burned by roadsides in peri-urban Kumasi and its abundance creates a problem for poultry farmers (Quansah *et al.*, 1997).

Compared with the peri-urban farming systems, in the urban backyard farms there appears to be slightly greater use of livestock manures (7% of respondents said that they applied manure to their gardens), direct recycling of crop residues by nearly half of the gardeners, and less dependence on mineral fertilizers (none of the respondents mentioned the use of mineral fertilizers on their plots). However, there is little active recycling of manures by the livestock keepers sampled in the other urban studies, with the notable exception of poultry manure, as Table 3.3.4 shows.

Although the use of black soil (dug from the bottom of heaps of market waste) has been recorded in Kumasi (Holderness, 1996), no mention of its use was made in any of the surveyed peri-urban villages. Night soil from the public latrines is collected for disposal in a few villages but does not appear to be recycled.

Inputs supply and demand balance

It has been indicated above that supply of organic soil ameliorants would appear to considerably outstrip demand. In an attempt to clarify and quantify the situation a study was carried out by means of:

1. Interviewing of key informants and accessing data on the availability of organic and inorganic resources with the potential to increase soil fertility.
2. Deriving estimates of the quantities of nutrients available from these sources of supply.
3. Compiling an inventory of soil improvement resources for urban and peri-urban Kumasi.
4. Interviewing key informants, accessing data and estimating the present use of the inventorized resources.
5. Collecting data on the potential future use of these resources.
6. Compiling a report on the present and potential uses of locally-available soil improvement products (Kindness, 1999).

Table 3.3.4. Disposal of animal manures by urban livestock keepers.

Disposal method	Respondents reporting disposal method (%)			
	Cattle	Sheep and goats	Pigs	Poultry
Thrown away	98	100	97.5	5
Deliberately used as soil ameliorant	2	0	45	95

Note: Some respondents mentioned that they used part of the pig manure for soil amelioration and part was thrown away. Also, 5% said that they used it in fish ponds.

Source: KNRMP, 1999.

The report considered the types and quantities available and sources of:

- municipal waste (domestic, industrial and commercial);
- night-soil and sewage sludge;
- livestock manure;
- sawdust;
- agro-industrial wastes from crop processing and livestock;
- black soil from waste dumps; and
- chemical fertilizers.

The soil fertility value of the different soil ameliorants was evaluated, and their present and potential future use was assessed. The present use of the available soil ameliorant resources is summarized in Fig. 3.3.1. The nutrients available from these resources are summarized in Tables 3.3.5 and 3.3.6.

Figure 3.3.1 shows that the only potential soil ameliorant resources used in any significant quantity are manures from poultry. Thus, it is clear that in peri-urban Kumasi, in terms of available principal plant nutrients, far more *organic* material which could be used as fertilizer appears to be wasted than the total quantity of *inorganic* fertilizer actually applied. The other potential benefits of the use of organic fertilizers, in terms of soil structure and microbiology, have not been assessed as the quantification of these effects is as yet at an investigative stage.

As noted from the PRA studies, farmers in peri-urban Kumasi have a general awareness of the benefits of organic manures for soil amelioration but lack detailed knowledge of the processes by which these benefits are manifested. Some mentioned the gradual release of nutrients; others mentioned that they believed that animal manures, if mixed in water and sprinkled on crops, had pest repellent properties. Others expressed concern at the possible harmful effect of residues from poultry medicines being present in their manure. Apart from animal manures, no other organic resources were used by farmers in our surveys, though they were aware that black soil was used locally in nurseries and that some people had tried composting.

Table 3.3.5. Nutrients available from the chemical fertilizers used in the peri-urban area.

	Quantity of fertilizer used in the peri-urban area (t)						Quantity of nutrients available (t)		
	NPK 15-15-15	NP 20-20-0	NPK 23-15-5	AS ^a	Urea ^a	Total	N	P ₂ O ₅	K ₂ O
1998 ^b	155	105	50	115	55	480	105	52	26
1997	140	105	48	115	39	447	95	49	23
1996	193	110	60	123	39	524	108	60	32
1995	18	12	13	30	15	87	21	7	3

Key: ^a Nutrient content of ammonium sulphate (AS) is 21% nitrogen; nutrient content of urea is 46% nitrogen.

^b 1998 figures are for January to end-November.

Source: Kindness, 1999.

Table 3.3.6. Total nutrient content of the potential organic soil ameliorants in Kumasi.

Soil improvement resources	Nutrient content (% fresh weight)				Total nutrient content of soil improvement resources (t year ⁻¹)								
	N	P	K		N			P			K		
					Min	Max	Av	Min	Max	Av	Min	Max	Av
Municipal waste	0.6–1.5	0.18–0.8	0.83–1.27		749	3136	1753	225	1672	818	1036	2655	1753
Domestic waste	0.6	0.18	0.83		796	1104	950	239	331	285	1101	1528	1314
Market waste	0.3	0.09	0.5		47	75	61	14	22	18	78	125	101
Night-soil and sewage sludge	0.6	0.09	0.25		468	655	562	70	98	84	195	273	234
Livestock manure													
Poultry manure	1.46–1.9	0.17–0.6	0.17–0.84		498	648	573	58	205	131	58	287	172
Other livestock manure (1996)	0.2–0.8	0.03–0.2	0.1–0.66		63	252	157	9	63	36	31	208	120
	0.6	0.13	0.99				333			72			549
	0.6	0.13	0.99				100			22			165
	0.5	0.18	0.42				64			23			54
Sawdust (1997)	0.1–0.25				3	23	11						
Agro-industrial wastes													
Brewery waste	3.0–5.51	1.22	0.15		176	324	250			72			9
Total (Mt year ⁻¹) ^a					2332	5562	4252	545	2293	1477	2304	4803	4237
Grand Total					2800	6217	4814	615	2391	1561	2499	5076	4471

^a The totals exclude night-soil and sewage sludge because only volume figures are available, not weights.
Source: Kindness, 1999.

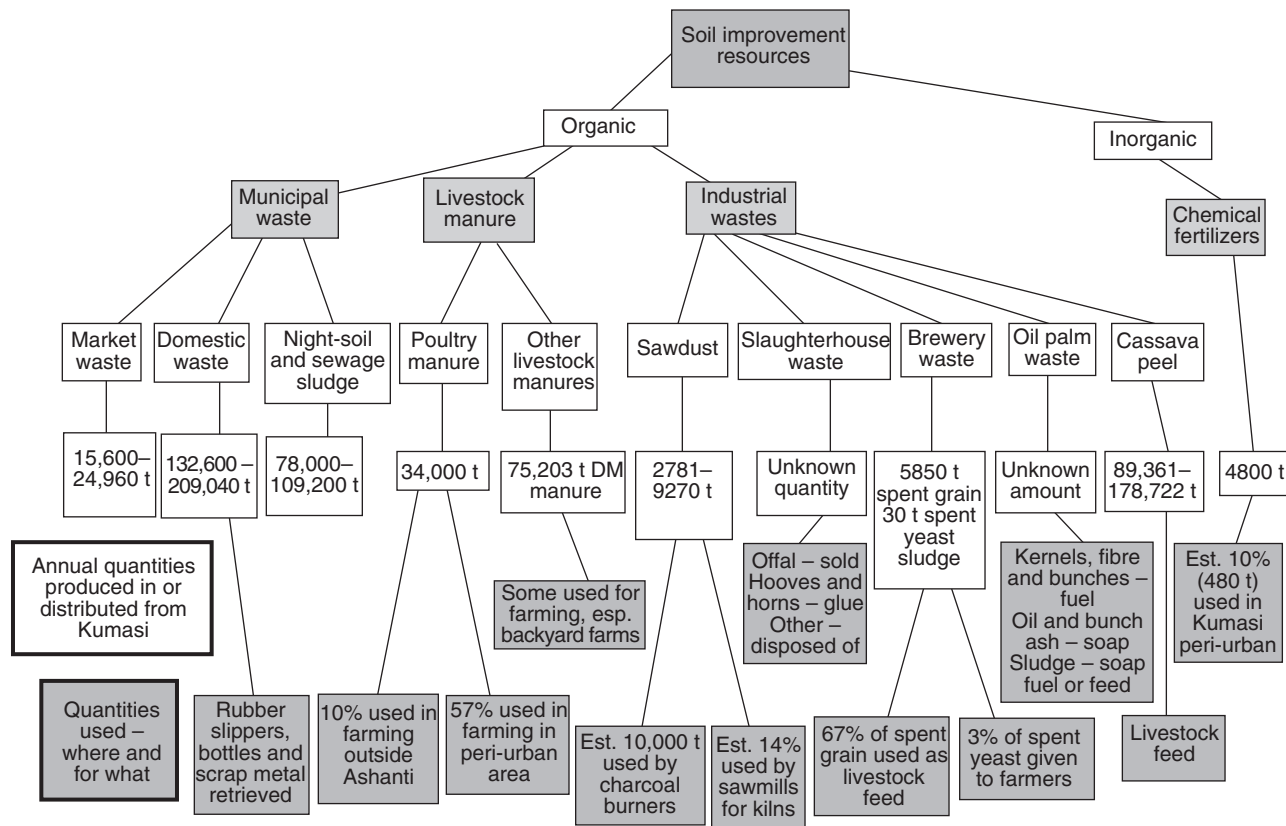


Fig. 3.3.1. Flowchart of production and use of potential soil ameliorant resources in peri-urban Kumasi.

Summary of main findings – farming systems

- Land-use patterns are changing within the peri-urban area. The change is unplanned and uncontrolled because there is no adequate town planning scheme. The effect is that housing is increasing and agriculture is decreasing.
- The types of crops cultivated are related to land availability and the proximity to an urban market. Currently, there is a shift from cultivation of traditional cash crops to more intensive vegetable cultivation and livestock systems (especially poultry) producing fresh produce for the urban market.
- Declining yields have been observed and farmers attribute this situation to the high frequency of cropping without long fallow periods and without artificial soil regeneration inputs.
- The urban land market is characterized by increasing competitive pressure on land. In the competition for land between agriculture and residential facilities, agriculture loses out. Migrant farmers and women are affected most.

Problems Identified

The inhabitants of Kumasi metropolis are, in general, faced with the dispossession of their land and dislocation of agricultural livelihoods, due principally to reallocation for building land. Those with no alternative means of support (i.e. those with a predisposition to poverty) are forced to continue to use the dwindling area of land available for their subsistence and income supplementation. By reducing the fallow period, soil erosion has increased and loss of soil fertility has become a serious constraint in agriculture.

In the context of poverty alleviation, the critical issues presently confronting farmers in Kumasi metropolis area include:

- continuing pressures on agricultural land due to urban expansion;
- growing scarcity of land for farming and rising cost of land;
- insecurity of tenure;
- uncertain and changing land tenure arrangements which encourage short term advantage over long-term security and husbandry;
- conflicts between traditional and state controls on land allocation and land use;
- in-migration to peri-urban areas;
- need to increase food production under rapid population growth;
- declining soil fertility;
- water pollution resulting from indiscriminate use of agro-chemicals in vegetable crop production; and
- lack of credit, particularly for women.

The greatest problem facing farmers in Kumasi metropolis is the growing scarcity of land. Sometimes the farmers who are affected by urban expansion are long-term residents of villages, especially women.

Recommendations

The ever-increasing demand for food by a fast growing urban population needing to satisfy conflicting demands for food, recreation, housing, and other necessities of life, requires a continuous effort to increase food production; to improve and maintain welfare of the population on a sustainable basis while ensuring environmental sustainability.

The immense and complex challenges resulting from urbanization and rapid population growth can be met, given sufficient resolve to:

1. Increase soil fertility through the application of organic manure (composting and poultry manure) in order to increase food production and remedy present inadequate supply.
2. Promote intensive use of available land for high value crops in response to increasing pressure of population on available land especially in the peri-urban areas.
3. Promote off-farm and on-farm income-generating activities, particularly among women, who are most affected by loss of farmlands due to urbanization.

Conclusion

Urbanization and population growth has brought pressure on land and its use. Changes in land use have, in turn, triggered changes in farming systems to meet the growing food needs of the people in peri-urban Kumasi. Generally, the changes appear to have been negative in terms of soil fertility and farm yields.

A solution to this problem would seem to lie in the adoption of farming systems based upon organic matter and application of poultry manure to maintain soil fertility as well as other sources that may be readily available to farmers to maintain soil fertility. In addition, farmers should be able to use the resources without incurring huge transport costs.

However, success of the recommended agronomic measures would be enhanced if more efficient land use and town planning strategies are adopted to ensure that productive agricultural lands are not easily given up for residential development.

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AN INTEGRATED WASTE MANAGEMENT STRATEGY FOR KUMASI

L. Salifu

Urban Environmental Sanitation (Urban IV) Project, Kumasi Metropolitan Assembly, Kumasi, Ghana

In Ghana, all district, municipal and metropolitan assemblies give urban sanitation and waste management a priority in their development objectives. However, their ability to contain the problems of waste management is deteriorating, because of rising capital costs for plant and equipment, increasing operation and maintenance costs, the rapid spatial and population growth of most urban areas with decreasing coverage levels, and the increase in levels of waste generated, confronted by increasing public demand for improved services.

In Kumasi, solid waste management (SWM) is simply inadequate. The Kumasi Metropolitan Assembly (KMA) solely responsible for SWM through its WMD manages to collect and dispose of about 50% of the waste output. The bulk of domestic refuse collection (> 90%) is by communal container systems (for Accra see Ituah-Jackson *et al.*, Chapter 3.2 this volume) with other sources of refuse not catered for. Payment for refuse collection is non-existent as it has been difficult to collect charges directly for the community-based collection system. House-to-house collection covers only 400 houses out of a potential of 12,000.

Because of its inability to handle SWM adequately, Kumasi has been supported largely in the delivery of environmental sanitation services over the past decade by central government/external donor interventions. However, as in other infrastructure and service sectors, the overuse of donated equipment and facilities to terminal ruin is the practice. Forward planning to meet incremental injection of vehicles and equipment and replacement requirements are not part of the normal 'management culture'.

The lack of independent budgetary and revenue control for SWM services by the KMA-WMD, inadequate projection of fiscal needs and capacity, lack of commercial orientation and the reliance on other revenue sources, which prevent gauging of real SWM is to a great extent responsible for the existing dismal performance in SWM. The mentioned constraints do not allow setting of incremental targets for revenue mobilization from sanitation services to meet costs for SWM. This institutional context and basic constraints have to be kept in mind while discussing SWM improvements up to waste recycling options.

There are several ongoing initiatives, such as the Urban Environmental Sanitation (Urban IV) Project and the Kumasi–Almere Micro-Enterprise Refuse Collection (MERC) Scheme, the latter with a major franchising component. Both aim at improved sanitation, including better institutional and financing mechanisms as well as private sector participation, and thus address basic problems, which certainly need the most emphasis.

A more complex concept of integrated disposal was presented by Salifu (1995). It has the ultimate goal of extending the life of solid waste disposal facilities. It is based on ‘back-end’ processing at disposal facilities. However, it appears feasible to implement a ‘front-end’ concept incorporating the first three of the four Rs (Reduction, Re-Use, Recycling and Recovery) with community participation. This pathway, compared with the former ‘back-end’ concept, may prove to be more cost-efficient and sustainable. With the biodegradable organic fraction (BOF) of Kumasi’s solid waste in the range of 65–75%, composting offers an attractive option for reducing waste volumes transported for disposal. However, caution needs to be given with respect to *source separation*, a much touted strategy. In Kumasi, as in other municipalities of Ghana, where over 90% of the collection is through communal collection, households may not readily adopt source separation. Implementing house-to-house collection as demonstrated for the MERC scheme seems a useful precursor of the process of inducing households to practice some level of source separation.

The assemblies may opt to provide Community Recycling Credits to communities which participate in house-to-house (and also pre-collection) schemes and go further to implement Material Recovery Schemes at the community level. What will be recovered will differ for different communities (or housing segments). High cost areas may opt for recovery of plastics and paper whilst low-income and newly developing peri-urban areas adopt small compost schemes.

Policy Issues for Integrated Disposal and Cost Effectiveness

In April 1999, the cabinet approved an Environmental Sanitation Policy (ESP) which tasks the assemblies to take action and promulgate appropriate by-laws to regulate environmental sanitation and prevent pollution within their areas of jurisdiction. Sections of the ESP relevant to the current discussion are those on Technology Choice (8.3.3), which states among others ‘that recycling of waste for industrial, agricultural and other uses shall be practised wherever it produces a net cost reduction or positive environmental impact’, and also that ‘the promotion of waste reduction shall be an integral part of waste management’.

Section 1.4.2 of Annex 2, Technology states that ‘composting shall be carried out using simple methods and on decentralized basis, as near as possible to the point of waste generation. It shall only be carried out if it results in the net savings to the Assembly in terms of reduced transport and landfill requirements and possible revenue (estimated with due regard to the limited market for compost)’.

Reduction in volumes of solid waste for disposal obviously will reduce transportation costs. For the MERC scheme, transportation costs (without costs of disposal) come to about US\$3.50 t⁻¹, and cost the KMA-WMD US\$126 week⁻¹ for coverage of 500 houses in the scheme. A 20% composting of the BOF will save up to US\$100 month⁻¹ in transportation costs. Moreover, a 20% reduction in BOF waste volumes, for disposal will not only reduce the Assembly's costs but also will extend the landfill airspace by nearly 5 years. With the current difficulty in securing land for disposal facility development, these are all the arguments to be made for reduction in waste volumes for disposal.

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3.4 Dar es Salaam

LINKING (PERI-)URBAN AGRICULTURE AND ORGANIC WASTE MANAGEMENT IN DAR ES SALAAM

S. Kiango¹ and J. Amend²

¹Urban Vegetable Promotion Project, Ministry of Agriculture and Co-operatives; ²Urban Vegetable Promotion Project, German Technical Co-operation (GTZ), Dar es Salaam, Tanzania

The chapter gives an assessment of the nutrient flows into Dar es Salaam, Tanzania, and within the city. It documents that there are large amounts of nutrients remaining in the city, but only a minor share is used productively for urban farming. Thus most nutrient flows end without recycling despite the fact that there are significant agricultural activities with a potential to produce and use, for example, compost.

Key words: East Africa, Tanzania, urban agriculture, waste management, organic wastes, composting, nutrients

Introduction

The cities in sub-Saharan Africa are growing at an exceptional rate of 5% annually. By 2020, more than 50% of the population of this region will be urban (World Resource Institute, 1998).

These cities are increasingly facing a multitude of challenges concerning housing, employment and organization of other basic services such as infrastructure, water and sanitation. Alone, the waste generated in urban areas will have quadrupled by 2025 (Sanio, 1998). Urban food security is another topic that is discussed increasingly. With the known shortcomings on infrastructure in sub-Saharan Africa, the supply of cities with agricultural products generated in peri-urban and rural areas and their distribution and accessibility within the city is receiving more and more attention. In the past, a rural-dominated and subsistence-based agricultural society made it easy to neglect topics like food

supply and waste collection. But the current steep population increase coupled with declining food production in Africa demands solutions for the growing cities of today and tomorrow (FAO, 1998).

Dar es Salaam is the biggest city and the industrial centre of Tanzania. It is situated on the shores of the Indian Ocean with an excellent natural harbour. Dar es Salaam is not only the gateway for goods into and out of Tanzania but also for landlocked countries like Uganda, Zambia and Rwanda.

The population of Dar es Salaam is estimated at three million with a yearly increase of about 8%. Around 50% of the population live below the poverty line (Ferreira, 1994). Nearly 60% are involved in the informal sector (Sanio, 1998). Currently internal growth and rural-urban migration contribute equally to the estimated 200,000 new inhabitants every year (CHS, 1995). Approximately 70% of the residents live in unplanned areas with limited services such as water and electricity (SDP, 1992; United Republic of Tanzania, 1996).

An increasing number of city residents no longer take it for granted that their basic needs are satisfied and public services are easily available. Access to these services, especially for the poorer strata of the urban population, is getting more and more difficult because of declining purchasing power and rising prices. Relying on their own food production has developed as one survival strategy for many households. Today livestock keeping and cultivation of crops can be observed all over the city.

At the same time 80–90% of the population, the majority living in unplanned areas, are not connected to a proper sewerage system and have to rely on pit latrines. Waste collection in the city can hardly cope with the amounts generated daily. Heaps of garbage pile up at street corners and are often dumped indiscriminately (De Vreede, 1998; DCC, 2001).

Up to now urban and peri-urban agriculture and waste management have been addressed separately. In this chapter the authors relate both topics through the flow of nutrients. Existing flows and linkages are elaborated, current gaps and future potentials for both waste management and urban and peri-urban agriculture are pointed out.

Methodology

The study is based on the review of secondary data for all the in- and outgoing flows and concentrates on organic material. Although not all flows can be described quantitatively, all sources were taken into consideration to give an indication about the biomass in circulation. The compiled information therefore can only give preliminary guidance and highlight certain aspects; further research is necessary to verify and complete the database.

The description of the urban production systems is derived from field experiences and adaptive research of the Urban Vegetable Promotion Project (UVPP) between 1996 and 1999 (Stevenson *et al.*, 1994, 1996, unpublished; Jacobi, 1997, unpublished; Jacobi and Amend, 1997; Kogi-Makau, 1998, unpublished) while considerable information on waste and waste collection

was provided by the joint waste management project of the International Labour Organisation (ILO) and the Dar es Salaam City Commission (DCC).

For the study of the flow of nutrients the following questions have been used:

- What are the sources for organic products/nutrients for the city?
- What kinds of products contribute to the flow of nutrients?
- How are they used or transformed in the city?
- Where do they end up?

Results and Discussion

Sources and destinations of nutrient flows for Dar es Salaam city

Three sources and destinations of nutrients are considered for the paper: (i) nutrients coming from or returning to areas outside the city; (ii) those imported from abroad; and (iii) those produced in the city itself. The bulk of inflow into the city is used directly for consumption while others first have to be processed. During and after processing and use there are certain portions of the products that are considered waste and are disposed of. A minor part of the processed goods are transported out of the city to other locations and sold there. We emphasize types of products and the weight of urban production versus external production. The categories mentioned in Table 3.4.1 are considered important in terms of nutrient flows and are discussed in more detail later.

Mineral fertilizers that contain nutrients in a concentrated form are not included due to their inorganic nature and their limited application in urban/peri-urban production.

Inflows into the city

Viewing the inflow into the city from non-urban areas one can distinguish three major categories of organic products: (i) the crop and livestock products for human consumption; (ii) the raw materials for animal feed; and (iii) other organic products coming into the city.

Table 3.4.1. Origin and use of organic products and materials considered in the survey.

Origin	Types of organic products	Use
Non-urban areas (rural, imports)	Agricultural products	Human consumption
	Agricultural products	Animal feed
	Other organic products and materials, forest products	Non-consumptive use and processing
Urban areas	Agricultural products	Human consumption
	Ornamentals, trees, bushes	Non-consumptive use
	Fodder	Animal feed

Agricultural products for human consumption

Staples, including grains and tubers, pulses, vegetables, fruits and animal products are produced in the rural and partly peri-urban areas of Tanzania to supply the urban markets of Dar es Salaam. They are channelled through the various markets to the households. After being processed and/or consumed at the household level they end up as organic waste, but with a potential for recycling (Fig. 3.4.1).

There is a very fragmented database for Dar es Salaam in terms of volume of overall food quantities circulating in the city, even more when it comes to differentiation of sources. Figures issued by the Marketing Development Bureau, Ministry of Agriculture and Co-operatives (MDB-MAC) (personal communication, 1999) can therefore only be seen as an example to illustrate the amounts. Table 3.4.2 presents official figures of maize, rice, and beans arriving at the three biggest wholesale markets in Dar es Salaam, for fruits and vegetables the main destination is Kariakoo, the biggest wholesale market for this kind of produce (MDB-MAC, personal communication, 1999).

Data for 1997–98 are minimal, probably due to heavy rains (El Niño) which reduced the transport of goods into the city. Urban production, however, was not negatively affected.

Taking into consideration that maize porridge (*ugali*) and rice are the main components in the traditional Tanzanian meal the amounts of grains and pulses channelled through the markets in recent years are surprisingly low and seem insufficient for a population of three million people. Only assuming 200 g per person day⁻¹, the total would be 600 t day⁻¹ or 220,000 t year⁻¹. There are several possible explanations:

- Incomplete data collection – a number of smaller markets do exist and people also rely on informal supply channels bypassing official data collection.
- City dwellers receive part of their food from the extended family in the rural areas and do not purchase food from the markets.
- Dar es Salaam residents rely on their own production in urban and peri-urban areas.
- Food aid coming into the country may also influence the volumes traded in the local markets.

Crops like banana, cassava, potatoes and sweet potato are not covered in the data collection, despite considerable amounts flowing into the city. These crops are important for various groups depending on their cultural background and consumption habits.

Food imports

Staples that are imported to the country commercially or as food aid contribute to the balance of nutrients coming into the city. However, it appeared difficult to distinguish how many of these nutrients stay in Dar es Salaam and

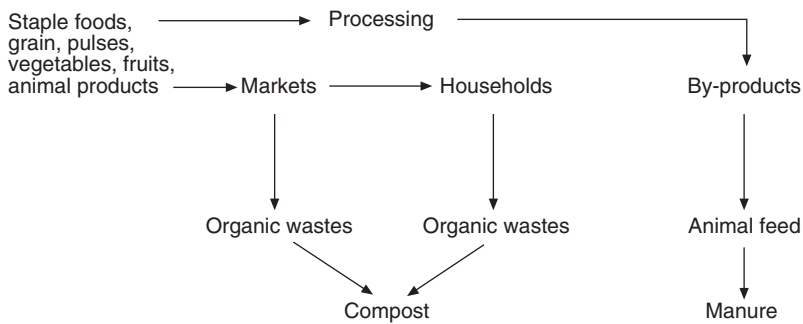


Fig. 3.4.1. Flow of nutrients for human consumption in the city.

how many are only in transit to other locations up-country. An average of 219,000 t of cereals was imported commercially every year between 1994 and 1996 (World Resources Institute, 1998). They were used mainly for brewing beer and for human consumption. Within the same period the amount of food aid declined from 114,000 to 24,000 t.

Animal feed

The raw materials for animal feed come from rural areas. They consist mostly of maize, but also other crops like rice, soybean, cotton and sunflowers and their respective milling by-products and press cakes. These materials are mixed into animal feed mainly for poultry. In 1996, nearly 100,000 t of animal feed were produced in Dar es Salaam. Approximately 30% of the feed was sold in the city, the rest transported back to rural areas (Sumberg, 1996).

Other organic products

The third category consists of organic products that come from agricultural or forest production or any other process. They are not for human or animal consumption but have other uses and directly find a market or are further

Table 3.4.2. Amount of maize, rice, beans and vegetables arriving per year at four major markets in Dar es Salaam (in 1000 kg).

Year (July–June)	Maize	Rice	Beans	Vegetables
1992–1993	53,440	33,670	27,210	n.a.
1993–1994	67,300	43,490	32,720	n.a.
1994–1995	78,800	50,080	43,180	n.a.
1995–1996	74,860	66,500	49,580	79,780
1996–1997	35,180	33,290	26,620	78,190
1997–1998	1,720	1,870	1,350	68,800
1998–1999	n.a.	n.a.	n.a.	81,160

processed in Dar es Salaam. Timber, charcoal, sawdust and wood chips, paper and processing by-products among others belong to this category. They finally end up, after being used and/or processed by people or animals as organic wastes. Because of their organic origin they make good raw material for composting.

Production in the city – urban agriculture

Dar es Salaam is one of several cities with considerable urban and peri-urban agricultural activities. A study by the Planning Commission and the Ministry of Labour and Youth (1995) came up with a figure of around 6.5% of the informal urban workforce being absorbed in agriculture, not taking into account the huge number of urban home-gardeners with their subsistence production. Dar es Salaam urban farmers concentrate on perishable products where advantages of short supply chains are most obvious. Cultivation of crops, especially of leafy vegetables is dominant in the inner-urban areas, while non-leafy vegetables come from peri-urban farms. About 95% of the city's supply of leafy vegetables, is produced on inner-urban plots. Due to their short production cycle, vegetables are suitable for locations where water is not available all year round and land use may change within a short time.

Livestock production does play a role in the supply of milk, eggs and meat for the city. Self-sufficiency for milk is estimated at 65%. Animal husbandry has been a well-perceived side-activity for government employees for a long time.

Crop production and ornamentals

Leafy vegetables (e.g. Chinese spinach (*Amaranthus* spp.), sweet potato (*Ipomoea batatas*)) dominate in inner-urban production. Aubergines, sweet and hot peppers, okra and tomatoes as well as fruits such as oranges, mangoes, bananas, papayas and pineapples are grown in the peri-urban sector. It is estimated that urban agriculture produces around 50,000–60,000 t of leafy vegetables year⁻¹ while peri-urban areas supply 25,000 t of non-leafy vegetables (Stevenson *et al.*, 1996, unpublished; Jacobi, 1997, unpublished).

With regard to ornamental gardens it is difficult to talk about productivity. Nevertheless biomass is produced that partly ends up as organic waste.

Animal production

The urban livestock population is an important link in the city's nutrient flow because it transforms nutrients into milk, eggs and meat, and provides manure as an end-product. The population is estimated to be about 34,000 head of cattle, 12,000 goats, 5,000,000 broilers and 1,500,000 layers (Ministry of Agriculture and Co-operatives, 1999). Urban and peri-urban dairy production caters for two-thirds of the milk demand (Kurwijila, 1995).

Similarly the bulk of eggs and chicken meat is produced in the city to supply the urban market. Only beef comes to a large extent from the rural area, partly from the peri-urban fringes.

Fodder

City by-laws forbid cattle from grazing. From the available data it can only be estimated how much fodder is collected daily. In general, fodder in Dar es Salaam consists mainly of grass and other plants cut along roadsides and on open spaces as well as coming from the peri-urban areas. Chamberlain (1989) states that an average cow can eat a quantity of dry matter equal to 2–3% of its body weight. The average live weight is estimated at 150 kg which corresponds with an intake of around 4 kg of dry matter or around 15 kg fresh forage. Five hundred t would be required day⁻¹ which amounts to 185,000 t year⁻¹ for the current cattle population.

Generation of waste and manure

Through the consumption and use of organic matter by humans and animals, solid and liquid wastes and manure are the final products. Their potential is relatively unexplored although nutrients in these products can certainly be returned into the production process.

Waste and sewage

Several international and national agencies (JICA, ILO, DCC) commissioned studies on waste generation in Dar es Salaam (JICA, 1997; Van de Klundert and Muller, 1998; DCC, 2001). The organic fraction of household waste and market waste amounts roughly to 1200 t day⁻¹ (see Table 3.4.3). Out of this, 500–700 t of compost could be processed daily (Lardinois and Van de Klundert, 1993).

Table 3.4.3. Daily waste generation in Dar es Salaam (in 1000 kg) and organic matter content (in %).

	Van de Klundert and Muller (1998)	JICA (1997)	DCC (1998)	% organic material
Household waste	975	1416	805	87
Commercial waste	53	27	60	57
Institutional waste	101	11	69	12
Market waste	200	34	245	95
Others (incl. industrial waste)	230	284	221	–
Total	1559	1772	1400	

However, to some extent decentralized recycling of nutrients occurs in the city. In residential areas that are not served by waste collection, garbage is dumped near the house and burnt occasionally. The soil from these dumps, rich in organic matter, is collected periodically and sold informally to nurseries or garden owners as compost.

The population of Dar es Salaam produces huge amounts of sewage that are so far disposed of but not recycled. Usually every house has its own septic tank or pit latrine that is emptied from time to time. The effluent is then brought to stabilization ponds or buried on or near the plot. This is true for 95% of Dar es Salaam residents; only 5% are connected to a sewerage system. In addition many of the city ponds are no longer functioning. This leads to sewage being discharged into surface drains, gullies, rivers, and finally the ocean (De Vreede, 1998).

Manure

Organic manure, especially chicken manure, is preferred in urban vegetable production. One hundred broilers produce 0.8–1.8 t of manure year⁻¹ while the same number of layers produce around 1–2.5 t (Mueller-Saemann, 1986; Drechsel, 1996). For Dar es Salaam this means about 91,250 t of chicken manure (Table 3.4.4).

In calculating the amount of cattle manure it is assumed that zero or hardly any extra litter is put down in the stables. Only the remaining and rejected fodder is used as bedding. Under such conditions 3–5 t of manure year⁻¹ seem feasible while there is a potential for double the amount if litter is used (Mueller-Saemann and Kotschi, 1994). For Dar es Salaam this would amount to approximately 100,000–170,000 t of cattle manure year⁻¹.

Due to the management system (free-roaming) goat manure is of minor importance. Nevertheless some of the nutrients will return to the cycle because the animals also defecate on grassland and improve biomass growth. According to Mueller-Saemann and Kotschi (1994), 10 goats produce 7 t of manure year⁻¹; we consider 2 t here. The goat population in Dar es Salaam (12,000 animals) therefore would produce 2400 t of manure.

Table 3.4.4. Manure produced in Dar es Salaam year⁻¹ (in 1000 kg).

	Animal population	Amount of manure year ⁻¹	Average NPK content t ⁻¹	Average NPK content total
Cattle	34,000	100,000–170,000 t	0.5% N 0.5% P 1% K	500–850 t N 500–850 t P 1,000–1,700 t K
Chicken	6,500,000	91,250 t	2% N 2% P 1% K	1,825 t N 1,825 t P 912 t K
Goats	12,000	2,400 t	0.5% N 0.5% P 1% K	12 t N 12 t P 24 t K

Source: own calculations (see text).

Established linkages and potentials for compost use

Potential sinks for organic material are required to arrive at more sustainable nutrient cycles. For organic wastes, urban and peri-urban agriculture have an even greater role to play considering urban agriculture's niche in the supply of fresh products for the city.

Besides agricultural production, ornamental gardening is on the increase. Recently, in connection with a nationwide campaign, the Dar es Salaam City Commission started promoting tree planting and put emphasis on recreational areas and open spaces. This sink might gain more importance in future.

All urban crop farming heavily depends on organic fertilizers (mostly poultry or cattle manure). There is a well established system between poultry keepers and vegetable producers, sometimes even leading to scarcity of poultry manure.

Cattle manure is only a second choice in urban agriculture because it may still contain weed seeds that germinate after application of the manure and cause weed problems and therefore additional work. However, at the neighbourhood level there is an intensive exchange of cattle manure from cattle owners to garden owners for their ornamental plots.

The urban production systems can be divided into various sub-systems: homegardens, market-oriented production on open spaces, and peri-urban mixed farming as well as livestock-based systems. Depending on the farming systems the absorption capacity and requirements are different.

Home gardens

Backyard gardening or home gardening is, by number of households involved, the most important production system in Dar es Salaam. Gardens are found throughout the city and gardening is carried out with minimal inputs on an individual basis. The majority of gardeners are women who usually produce only for home consumption. With an average garden size of 40–80 m² the food supply function for city markets is negligible, while at the household level home production contributes to the food supply and/or the household budget. So far recycling and use of organic waste have been difficult and not well established due to the small amount of organic material produced by an individual unit. Decentralized community-based waste collection would generate sufficient amounts for composting, make compost accessible in the neighbourhood, and could therefore increase the willingness and ability to intensify own production. Despite the fact that the quantity of compost required by an individual homegardener is minor, the magnitude of homegarden areas might still present a potential that is currently underdeveloped.

Open space production

It is estimated that in the inner city of Dar es Salaam (about 200 km² of the total 1350 km² of the Dar es Salaam city region) around 400–500 ha open space are cultivated with an average plot size of 700–950 m² (Stevenson *et al.*, 1994, unpublished; Jacobi, 1997, unpublished; Yachkaschi, 1997). Open spaces are characterized by year-round market-oriented production of mainly leafy vegetables. This production system relies on poultry manure and can be considered as the biggest customer for poultry manure (Table 3.4.5). The link between open space production and urban poultry keeping can be taken as a good example of the recycling of nutrients.

In 1995, Tanzania imported 58,000 t of mineral fertilizers. If chicken manure is substituted by compound fertilizer (NPK 15:15:15) Dar es Salaam open space production would require roughly 2500–6500 t which is equivalent to approximately 5–10% of the country's total fertilizer import.

Open space production is the most fragile among urban production systems. Most producers have insecure land rights and depend on informal agreements, or use of land is tolerated by city authorities. An intensified sink function (also for processed organic waste) is possible, but will depend on a variety of factors like political frameworks (town planning, land tenure) to maintain and maybe even encourage urban production on open spaces as well as accessibility, price, and quality of the processed organic waste.

Peri-urban production

For this chapter spatial city expansion over the last 5 years is considered as peri-urban, i.e. those areas with minimal construction or not completely developed. Here, the production systems are very heterogeneous, ranging from full- to part-time farmers and from subsistence to intensive market-oriented production. Staples, tubers, fruits and vegetables as well as animal husbandry occur. Stevenson *et al.* (1996, unpublished) estimated that about 35,000 farming households with an average farm size of 2 ha are involved in

Table 3.4.5. Estimated use of chicken manure in open space vegetable production.

Estimated surface area of open spaces in the city	No. of cultivations year ⁻¹	Average amount of NPK per cultivation and ha	Average amount of chicken manure per cultivation and ha	Total amount of chicken manure year ⁻¹	Total amount of NPK year ⁻¹
400–500 ha	5–10	200 kg N 200 kg P 100 kg K	10,000 kg	20,000 t – 50,000 t	400 – 1,000 t N 400 – 1,000 t P 200 – 500 t K

Source: own calculation, Jacobi (1997, unpublished).

peri-urban fruit and vegetable production in the fringes of Dar es Salaam, and about 44% of the daily milk demand is generated in this belt as well as a high percentage of selected non-leafy vegetables (Stevenson *et al.*, 1996, unpublished; Sumberg, 1996).

Unlike the environs of other cities in sub-Saharan Africa, Dar es Salaam's peri-urban agriculture is still small- (to medium-) scale, both in terms of hectares under cultivation and inputs used. Projecting a continuous increase in urban population and future city expansion, intensified production in the peri-urban belt is conceivable and could be a tremendous sink for organic matter.

Ornamental gardening and city parks

Dar es Salaam still has a number of low-density areas preferred by the medium- and high-income residents of the city. The plot sizes all favour (tree, shrub) gardening around the house. Already there is an established supply of 'fertile soils' coming from the peri-urban areas to improve garden soils. In addition, more and more small-scale nurseries are developing to satisfy the demand for ornamental plants. The city itself also puts more emphasis on recreational areas/city parks for its residents. Here both the demand and the capacity to pay for a quality product can be assumed.

Livestock-based systems

Livestock, especially in low-density and peri-urban areas is often combined with cropping systems. Mlozi (1998, unpublished) found in low-density vegetable production systems that half of the respondents kept livestock. In mixed systems the classical nutrient cycle can be observed. However it depends on the size of both the crop production and animal husbandry if the system is a net source or sink for organic manure/compost.

Conclusions and Recommendations

The inventory of nutrients and their flow into and within the city indicates clearly that there are tremendous amounts of nutrients flowing and remaining in the city. Currently only a minor share, mainly chicken and cattle manure, is used productively for urban farming. The main portion is disposed of as unsorted organic and inorganic waste and presents an increasing logistical and environmental challenge to city authorities. Thus most nutrient flows end without recycling despite the fact that there are obvious agricultural activities with the potential to produce and use, for example, compost. Filling this gap in the future – at least partially – is a demanding task for various stakeholders in Dar es Salaam.

Currently solid waste management in Dar es Salaam is in a privatization phase. This move was caused by the large quantities of waste generated by the city, and the absence of adequate collection services. In 1992 only about 5% of the waste generated daily was collected and then offloaded on two dump sites. Now private contractors, community-based organizations, and private companies, are being encouraged to take over the waste collection. However, with more systematic collection there is also a fear that landfill capacities might be limited.

The Dar es Salaam City Commission strongly supports the involvement of communities and community-based organizations in solid waste collection and encourages decentralized concepts at ward levels (DCC, 2001). The concept of community-based compost production is interesting in several ways:

- Composting uses an as yet unused fraction of the waste.
- Amounts of waste that have to be brought to collection points and later transported and offloaded on the city dump sites can be reduced.
- Groups can raise awareness about the benefits of compost in their neighbourhood and market it as organic fertilizer. This can add value to the waste and increase the economic benefits for waste collection.
- Compost can be used for agricultural activities in the neighbourhood and increase food production or intensify ornamental gardening.
- It offers small-scale vegetable producers in the community access to adequate amounts of organic fertilizer near their homes and improves input supply.

The city authorities acknowledge that composting is one way to make use of the organic fraction of the waste and at the same time reduce the amount of waste (DCC, 2001). In fact, several experiments in Dar es Salaam have shown that it is possible to produce good quality compost with limited investment. In all cases suitable technologies have been found while social and organizational problems have been more difficult to overcome. Waste separation at source (organic/inorganic fraction) is a precondition for any future use and a major challenge. Only a quality product available at affordable prices within the reach of the customers can gain the necessary acceptance and compete with established nutrient sources like manure and to a certain extent mineral fertilizer. While separation at source of household waste depends on the willingness of the individual household member, market waste is nearly pure organic matter that hardly needs further separation and therefore presents an ideal entry point for composting activities, making the product available and known to potential buyers.

Marketing of the processed organic matter, however, is seen as a serious problem. The advantages of compost compared with mineral fertilizers and even animal manure are not widely known. Additionally, when it comes to pricing, compost will have to compete with manure that has lower transportation and labour costs.

Improvements for liquid waste management are also proposed by the authorities. However, considering the even more difficult hygiene problems connected with the handling of night-soil, proposals for recycling for (peri-) urban agriculture appear to be too ambitious for Dar es Salaam at present.

Despite strong obstacles there are still many advantages that favour the idea of processing at least a portion of the organic waste into compost and partly closing the nutrient cycle: the available amounts of organic matter in the cycle, high demand for urban agriculture, increasing interest in ornamental gardening, political will that favours decentralized community-based waste collection, and more sustainable city development.

Combined efforts by city authorities, ward officials and local leaders can additionally influence the attitude in this direction. Only when all concerned groups unite and a favourable climate for both waste collection and composting as well as urban agriculture is created can a more sustainable flow of nutrients be achieved in Dar es Salaam.

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3.5 Lomé

URBAN AGRICULTURE IN LOMÉ

M.E.A. Schreurs and H. Van Reuler

*International Institute for Soil Fertility Management (IFDC-Africa),
Lomé, Togo*

Urban agriculture in Lomé produces vegetables, spices and herbs on the shoreline and maize and cassava on elevated parts of the city. Soil amelioration with organic and inorganic fertilizers is highly recommended, but only small amounts of agro-industrial waste are recycled. As urban vegetable farming has developed with insufficient support, guidelines for adequate crop management and site-adapted use of inputs are required.

Key words: West Africa, Togo, urban agriculture, socio-economics

Introduction

The population of Lomé has increased from 200,000 in 1970 to over 1 million in 1998. At the same time the area of the city has increased from 20 to 120 km². Urban agriculture is carried out beside the sea (irrigated cash crops) and on upland sites in the city (rainfed farming of maize, cassava, beans and tomatoes). Here crops are often grown along roadsides, on open spaces or on backyard waste dumps (Kessler, 2000, personal communication). The number of vegetable farmers active along the ocean has increased from about 400 in 1980 to over 1000 in 1998. The increase can be related not only to the expanding city but also to a poor national economy where (peri-)urban agriculture provides substantial employment opportunities. This chapter focuses on the production of commercial crops along the shoreline of Lomé.

Crop Cultivation and Nutrient Sources

The main crops cultivated are vegetables, especially cabbage, lettuce, carrots, African spinach, and onions as well as spices and herbs (dill, basil and chives), the latter mostly for export. Crops are grown on plots varying in size from 25 to 50 m². The soils along the shoreline are very sandy, thus requiring frequent watering (groundwater is found at 2–3 m depth) and nutrient inputs. Soil properties depend on the length of the cultivation period, e.g. due to frequent application of organic fertilizers a dark surface horizon may develop.

Field observations indicate that high amounts of pesticides are used. With respect to nutrient inputs, Schilter (1991) reports that mineral fertilizers (NPK) are preferred to organic fertilizers because of availability, low transport costs, ease of handling and availability in small amounts. However, this was before the devaluation of the FCEA and the reduction of fertilizer subsidies. Recent observations show that cow dung and poultry manure are the main products used, and to a smaller extent agro-industrial residues from breweries, cocoa production and cotton processing. As manure is not very abundant, the production of compost using organic household or market waste would be an option¹ to increase the low organic matter content of the soils and to increase the water-holding capacity of the sandy texture.

However, for the cultivation of spices and herbs, farmers are advised against the use of organic manures to avoid contamination. If farmers need them, the company that buys the products provides mineral fertilizers and the costs are recuperated at harvest. Another observation is that farmers now seem to prefer combined use of organic and mineral fertilizers. Common application rates in combination with 10 t ha⁻¹ poultry manure, for example, are 200 kg ha⁻¹ for NPK (15–15–15) or 100 kg ha⁻¹ for urea (Kouvonou *et al.*, 1999).

Socio-economic Conditions

The main area used for vegetable production is located in the industrial zone. The Municipality of Lomé owns this land. Farmers have been asked to pay fees for temporary land use, however, they can be expelled if the land is required for construction purposes (Adotevi, 1997; Kouvonou *et al.*, 1999). To provide more land security and create jobs, the Municipality of Lomé should designate – at least temporarily – more areas for urban agriculture.

If one compares the data provided by Schilter (1991) and Kouvonou *et al.* (1999) the number of full-time farmers has increased and the number of part-timers has decreased. Three explanations are possible: first, due to city expansion, more rural areas have been absorbed; second, part-timers have become full-time farmers for economic gain (cf. Table 3.5.1); third, part-timers are forced to become full-time farmers because they have lost other jobs.

¹Recently, a pilot compost station started operation in the Akodessewa quarter of Lomé (see Kessler and Helbig, page 133 this volume).

Table 3.5.1. Costs and benefits of peri-urban farmers in relation to plot size (Schilter, 1991).

Costs and benefits (FF)	Plot size m ²			
	780	1,173	2,600	5,740
Annual production costs	1,843	1,557	4,501	36,864
Annual gross benefits	6,575	18,753	44,820	91,583
Net annual benefits	4,732	17,196	40,319	54,719
Net monthly benefits	394	1,433	3,360	4,560
Net annual benefits per 100 m ²	607	1,466	1,551	953

Annual production costs are affected considerably by farm size due to the need to hire labour (Table 3.5.2). Net monthly benefits, as estimated by Schilter (1991; cf. Table 3.5.1) appear to be too high in comparison with more recent estimates of 1800 French francs (FF) for a plot size of 3400 m² (Kouvonou *et al.*, 1999). However, all these figures do not consider family labour input.

Labourers are hired on a temporary basis. Table 3.5.2 shows that farmers who cultivate more than 4000 m² rely entirely on hired labour (Schilter, 1991).

Marketing

Women play a major role in the marketing of peri-urban products. Sometimes traders order the products beforehand and the oral contract is based on confidence. The vegetables are bought on credit and the farmer receives money when the trader has sold all or most of the products. The final amount of money received may differ from the price earlier agreed as demand and supply might have changed during the growing period (Schilter, 1991). But another case can exist where the farmers obtain a loan from the trader for seeds and other inputs (see Kessler and Helbig, page 133 this volume).

The total production of spices and herbs is bought by one company and exported to France. The final price farmers receive depends on the quality of their products.

Table 3.5.2. Use of family and hired labour in relation to plot size (Schilter, 1991).

Plot size (m ²)	Family labour only		Family + hired labour		Total number
	Number	%	Number	%	
50–1000	16	76	5	24	21
1000–2000	12	46	14	54	26
2000–4000	5	26	14	74	19
> 4000	0	0	9	100	9
Total	33	44	42	56	75

Outlook

At present, the Togolese economy is in poor shape and consequently the purchasing power of the population is low. Moreover, the expatriate community is very small, partly for political reasons. Under improved conditions there could be a much higher demand for products provided by urban and peri-urban agriculture. As this type of farming has developed without much support in Lomé, guidelines for adequate crop management, especially use of inputs, are not available. IFDC-Africa has initiated activities to optimize fertilizer use and integrated plant nutrient management. Commercial urban agriculture also offers an excellent opportunity for linking farmers with input/output markets, credit systems, and extension services and in this way their living conditions can be improved substantially. Such a development may serve as an example for a general intensification of agricultural practices in Togo.

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ADDING VALUE TO COMPOST FROM URBAN HOUSEHOLD AND MARKET REFUSE IN LOMÉ

A. Kessler¹ and J. Helbig²

¹Humboldt-University of Berlin, Institute of Agricultural Sociology, Berlin, Germany; ²Humboldt-University of Berlin, College of Agriculture and Horticulture, Department of Phytomedicine, Berlin, Germany

Since September 1999, a pilot compost station using organic wastes from households and markets has been running in Lomé, Togo. The station aims at the production of compost for vegetable farmers, not only for soil amelioration but also for phytosanitary purposes. Similar stations have also been established in Senegal and Guinea.

Key words: West Africa, Togo, composting, waste management, urban wastes, farmers, pest control, plant protection

Introduction

While waste management and waste disposal are major urban problems worldwide, compost production has proved in most cases to be an unattractive economic option (UNEP, 1996). The situation might change if it is possible to add value to the compost by using it also for pest management. The project 'Use of composted organic waste from urban households for phytosanitary purposes in peri-urban agriculture of Western Africa' was set up to study the potential of this option with funds from the European Commission.

The project is carried out as collaboration of three African and three European partners. The African partners collect waste and run pilot compost stations in selected urban areas of Lomé and Tsévié (Togo), Rufisque-Dakar (Senegal), and Conakry and Timbi Madina (Republic of Guinea). The establishment of the compoststations is accompanied by socio-economic research at household and at farmer level. The project is also in regular contact with the municipal waste management authorities.

Waste Collection and Composting

In Lomé, about 40 non-governmental organizations (NGOs) collect household waste to dump at official dumping sites in each of Lomé's five arrondissements. The NGOs collect fees from the households for this service. From each of these dumping places the waste is transported to the final overall dumping place in Lomé by private companies paid by the municipal authorities. Municipality waste collection still exists in some streets of the city. The compost station in Lomé was installed in September 1999 by Institut Togolaise de Recherche Agronomique in the harbour area of Lomé.

Close to the compost station (quarters of Akodessewa, Wete, and Ablogame), four project teams² are in charge of the household waste collection of organic waste. They also collect fees for the service and can give sanitary advice. The teams bring the waste with push-cars ('trucks') to the compost station at the road station of Akodessewa. Although some households have difficulty in paying regularly and on time, these teams served more than 300 households in August 2000 and the number is still increasing. Currently, the project promotes waste separation (organic and other waste) at the household level. The results will show whether composting can be attractive for the NGOs involved in the waste collection process.

To minimize transport costs, the compost station is located next to the fields used by the urban farmers. Due to the high quantities needed to fertilize the soil, transport to the field is a serious problem for farmers who do not have mechanized transport.

At the compost station, a team of six 'composters' separates the organic waste from the non-organic composites that are collected by the enterprise in charge of the arrondissement. Due to sandy soil and unpaved backyards the percentage of organic matter is only about 30% of the total household waste, while sand constitutes about 40%. The station also receives some organic waste from a local market. Regularly, the organic waste is cut up and mixed with manure to get an adequate C:N ratio. The heaps are watered in the beginning and at each turning. Every 4–6 weeks a heap is turned, allowing the compost to ripen over 3 months. During this period the temperature is controlled daily to assure high quality and a certain safety standard. All work is done manually.

The Vegetable Farmers

Along 20 km of the shoreline, vegetable farmers cultivate cabbage, lettuce, carrots, onions and different varieties of African spinach. The land is mainly public (70%), such as the land in the harbour area of Lomé and the industrial zone (Moglo, 2000). After protests against fees, land use is currently free. Only 10% of the urban vegetable farmers own the land they cultivate. The transmission of public land from one user to another takes place by recovering

²Each with two organic waste collectors and one sanitary advisor.

the investment for the irrigation infrastructure (wells, cisterns), i.e. farmers pass on water access and not land rights.

Most vegetable farmers are young people: about 60% are between 25 and 40 years old, and the majority (80%) are men. Nearly 90% of the interviewed farmers say that vegetable farming is their main activity. About 60% of the farmers use casual labour for irrigation and other activities (Moglo, 2000). Vegetable farming therefore offers important job opportunities. The farmers irrigate two to four times per day by extracting the water by hand or with motor pumps from the cistern. The water-table is at a depth of 2–3 m. Fields are irrigated using cans or tubs. Compost could reduce the frequency of irrigation as compost could improve the water-holding capacity of the soils.

The sandy soil obliges the farmers to use fertilizers. Most of them use chicken and cow manure as basic fertilization and chemical fertilizers during the vegetation period. Also cotton oil cake from the agro-industry of Lomé, which is located near the vegetable farmers, is used. A few farmers use herbs and weeds for green manure. The preparation and application of compost is not common due to lack of knowledge or related tradition and/or manpower. Farmers also expressed concerns that compost can promote weeds, which is in fact likely because of the poorly maintained farm 'composts' observed. Farmers who know something about compost have learnt this in school, on training courses or through NGOs or colleagues. Most of the farmers interviewed do not mind using waste for compost and using this compost in food production. Farmers who indicated interest in the project compost, said that they would pay a similar price as for manure.

Most of the vegetables are sold on the field to women traders who do the harvesting themselves. Usually, they transport the products as head loads or for longer distances on push-cars or by taxi to the markets of Lomé where they sell them to small traders. These small traders sell at the market or from house to house. Hotels and restaurants often order directly by asking the farmer to cultivate a certain amount and kind of vegetable. The economic situation obliges some farmers to take credit from vegetable traders for fertilizers, seeds or pesticides, which they pay back after harvest.

Only a few farmers belong to professional associations. The public extension service for agriculture provides two extension workers for about 1500 vegetable farmers. The extensionists work without vehicles, therefore it is not surprising that only a few farmers are in contact with them. However, the allocation of extension workers shows at least a certain level of official recognition for urban agriculture.

Phytosanitary Aspects

The vegetable farmers recognize diseases and insects that attack their crops but their knowledge appears to be limited since they have difficulties in differentiating the diseases and/or insects. On the other hand, the farmers are very

familiar with the application of pesticides. They like to mix the different pesticides to assure high efficacy in pest control. Most of them use cotton or cocoa pesticides sold on the unofficial market and originating from Benin, Ghana and Togo. They are cheaper than legal pesticides in the shop and are sold also in small quantities (as in a teacup). Most of the farmers did not finish primary school and give little attention to the safe use of pesticides.

The project aims to find out if compost extracts prepared from urban household waste can control plant diseases and to analyse the corresponding mechanism. Farmers interviewed were not aware of this compost benefit but understood the idea after explanation.

The project works on cassava in Tsévié, lettuce in Lomé, tomatoes in Dakar, potatoes in the Fouta Djallon Highlands, and sweet potatoes for leaf consumption in Conakry. Modern varieties of cassava are often especially sensitive to diseases caused by fungi. For tomato and potato the project is working on diseases caused by *Alternaria* and *Fusarium* species.

Station trials are taking place or are finished (as in Dakar). On-farm trials are planned for the next season. The trials used large amounts of the compost produced so far.

Two of the collaborating institutions in Europe are involved in investigating the principal mechanism in the laboratory. First results show the ability of the compost extracts to suppress diseases caused by fungi. If this characteristic of the compost can be confirmed in further trials, the application of compost and compost extracts could be integrated into the existing plant protection strategies. A multipurpose compost could be sold at a higher price, thus becoming economically more feasible than compost that is only a soil ameliorant.

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3.6 Optimizing Nutrient Recycling and Urban Waste Management – New Concepts from Northern Europe

J. Magid¹, A. Dalsgaard² and M. Henze³

¹Department of Agricultural Sciences; ²Department for Veterinary Microbiology, Royal Veterinary and Agricultural University, Frederiksberg, Denmark; ³Department for Environmental Science and Engineering, Danish Technical University, Lyngby, Denmark

Night-soil together with solid organic household waste constitutes about 1% of total household waste volume, but contains 82–87% of the nutrients. The NUTRAP¹ centre in Denmark is working on concepts to recycle these nutrients into fertilizer.

Key words: Northern Europe, nutrients, urban areas, waste management

In Northern Europe today, waste management systems have developed to maturity without primary concern for recycling. These systems have been designed only to ensure a high local hygiene standard. More recently environmental concerns have been the driving force behind a technological development of sewage treatment with biological removal of N, P and organic matter from the waste water. This technology addresses some immediate problems in the aquatic environment, but the sewage sludge from the treatment plants contains considerable quantities of xenobiotic compounds and heavy metals and only a fraction of the nutrients that entered the urban areas, thus making the sludge an unattractive fertilizer source. In recent years there has been concern about the sustainability of this state of affairs, as well as concern about the fate of the final waste deposits in the environment.

Recycling of waste from the food industry has been estimated to be approximately 99% in Denmark (Danish EPA, 1998) since waste from this sector is either used for fodder or directly as fertilizer or after biogas production. However waste management in urban households, the service sector and other industries poses a separate challenge. State-of-the-art systems are

¹ www.agsci.kvl.dk/NUTRAP

based on the collection of solid waste (often separated in organic and inorganic fractions) and treatment of waste water. The sewerage system receives black water (physiological fraction), grey water (washing and cleaning), and storm water runoff. The composition of waste sources from households in Scandinavia (Table 3.6.1) clearly indicates that the urine and faeces fraction by far contains most of the nutrients in the household waste.

Night-soil and solid organic household waste theoretically constitute 1% of the total household waste volume (including waste water), but contain 82–87% of the nutrients. By removing this nutrient-rich household waste (NRHW) the need for nutrient removal from sewage would be minimal or non-existent. If necessary further measures to limit the P content of detergents could be taken. In practice, systems need to be developed in order to manage NRHW from urban areas. A realistic estimate based on minimal flushing systems indicates the volume of this nutrient rich waste to be no more than 2–3 m³ per person year⁻¹. In Scandinavia such systems have been developed and tested for rural areas without sewerage systems, and currently trials with such systems are being made in urban areas.

The development of such systems could have major implications for the environment, public health and recycling of nutrients to the land. In order to address these issues in an integrated way NUTRAP was formed: Centre for Appropriate Technologies for *Nutrient Recycling from Human Waste to Agriculture in Peri-urban Areas*.

The urban fertilizers that can be derived from the NRHW fraction compare favourably with sewage sludge and pig slurry with regard to content of heavy metals (Table 3.6.2). We are currently in the preparatory stage of launching a programme to assess such urban fertilizer effects on health,

Table 3.6.1. The composition of waste sources from households in Scandinavia (g per person day⁻¹) and their relative contribution to weight and nutrient (N, P, K) content.

	Total	Physiological		Kitchen		Bathroom Grey water
		Faeces	Urine	Liquid	Solid	
Dry matter	235	35	60	40	80	20
COD	220	60	15	45	90	10
BOD	90	20	5	30	30	5
Nitrogen	15.7	1	11	1	1.7	1
Phosphorus	2.8	0.5	1.5	0.2	0.3	0.3
Potassium	4.7	1	2.5	0.4	0.4	0.4
Contribution to:						
Waste weight (%)		0.1	0.8	7	0.16	92
N in waste (%)		6	70	6	11	6
P in waste (%)		18	54	7	11	11
K in waste (%)		21	53	9	9	9

Source: Modified from Eilersen *et al.* (1998).

BOD, biochemical oxygen demand; COD, chemical oxygen demand.

Table 3.6.2. Average concentrations of nutrients and heavy metals (mg kg⁻¹ dry matter) for sewage sludge, compost, human excreta and pig and cattle slurry.

Component	Sewage sludge	Compost	Human excreta	Pig slurry	Cattle slurry
Nitrogen	45,000	9,000	130,000	127,000	55,000
Phosphorus	32,000	2,000	20,000	28,000	11,000
Potassium	3,000	3,500	35,000	72,000	50,000
Cadmium	1.5	0.3	0.2	0.5	0.6
Mercury	1.4	0.1	0.7	< 0.1	< 0.1
Lead	57	30	0.3	3	4
Nickel	25	10	1.7	14	8
Chromium	40	10	0.4	10	3
Zinc	775	150	120	1,500	150
Copper	300	50	15	630	65

Source: Eilersen *et al.* (1998).

environment and ecosystem integrity. Furthermore NUTRAP has been commissioned to make an overall assessment of opportunities and barriers for nutrient recycling from urban areas to peri-urban areas, as well as a technological assessment of sewerless waste management.

Since sewerage systems are very costly and often not established in urban areas of developing countries the systems mentioned above could prove valuable in such a context, since it could help to avoid some of the mistakes that we have made in our 'developed' societies, that have proved so detrimental (or at least not beneficial) to our surroundings. A key element in the recycling of nutrients is the distance from production of the waste to disposal. Here, urban areas in developing countries with local agriculture fulfil the distance criteria. Currently NUTRAP's activities are limited mainly to Denmark, but we are considering possibilities for international collaboration.

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Modelling Urban and Peri-urban Biomass and Nutrient Flows

4.1 Assessing the Potential of Organic Waste Recycling through the Analysis of Rural–Urban Carbon Fluxes

C. Binder and N. Patzel

Swiss Federal Institute of Technology (EAWAG), Dübendorf, Switzerland

To estimate the order of magnitude of the biomass and carbon fluxes between rural and urban areas a material flux analysis was carried out in a case study from Colombia. The analysis includes estimations of the amount of organic waste generated and its potential for fertilization.

Key words: South America, Colombia, organic wastes, recycling, organic carbon

Introduction

In the last two decades, interest in using organic wastes from urban areas in rural areas has grown. Research topics refer to: (i) the treatment of organic wastes to minimize their health and environmental impacts (e.g. Shuval *et al.*, 1981; Cross and Strauss, 1985; Obeng and Wright, 1987); and (ii) the effects of incorporation of treated organic wastes into soils (e.g. Shuval *et al.*, 1981; Baccini and Von Steiger, 1993; Pagliai and Antisari, 1993; Paine *et al.*, 1996). Even though the use of organic wastes in agriculture involves the link to urban centres, studies that quantify the real and potential flows of organic carbon and nutrients between rural and urban areas are very scarce.

This chapter summarizes some of the results previously described by Binder (1996) and Binder and Patzel (1999) taking the Municipality of Tunja, Colombia, as a case study. The emphasis of this chapter is on the carbon fluxes and the potential of organic waste for soil carbon replenishment. Accordingly, the chapter addresses two major questions: 'How much organic waste is generated in the urban and rural areas?' and 'How large could the application rates of compost be?'

Materials and Methods

Geographical context

Tunja is the capital of the Department of Boyacá in Colombia. It is located in the eastern chain of the Andes and has a total municipality area of 117 km² and a population of 114,000 inhabitants (DANE, 1994). The urban area is located in the bottom of a valley and covers about 10% of the total area and houses 95% of the inhabitants. Due to its altitude (2800 m asl) and geographical location the average temperature in the region is 13°C, with an average night-time temperature of 5°C and an average day-time temperature of 20°C. There are two wet and two dry seasons with an average rainfall of 590 mm year⁻¹. Most soils in Tunja developed after the last glaciation and can be classified as Cambisols (Inceptisols). Soil texture is usually sandy loam, soil organic matter is about 1%.

Land use in rural Tunja is divided into pasture for meat and milk production (about 41% of the total area), arable agriculture (about 40%) and other land uses including forests and other areas (about 9%). In the arable area, farmers produce potatoes, wheat, oats, maize and sorghum. According to URPA (1995), about 76% of the farmers in Tunja are smallholders with plots smaller than 1–3 ha, using 22% of the total agricultural area. In contrast, about 3% of the farmers have plots larger than 20 ha and use over 36% of the total agricultural area.

Waste management systems in Tunja

About 70% of the population in urban Tunja is served with regular waste collection. The municipality produces waste at about 0.33 kg per capita and day which adds up to 49 t day⁻¹ or approximately 18,000 t year⁻¹. Households produce around 80% of the total waste (Gorraiz, 1988). The waste is disposed of on a dumping site and covered irregularly with soil. Of the wastes generated in households 73% are organic material.

Approximately 92% of the urban and 3% of the rural population are connected to a sewer system. The sewage is discharged into the surface water without any treatment. Thus, the surface water leaving Tunja is heavily

contaminated with sewage. Farmers of the downstream region use this water for irrigating their pasture plots adjacent to the river (EAAT, 1993; DANE, 1994). Currently no efforts are made to recycle these organic wastes for agricultural production.

Material flux analysis (MFA)

MFA was applied. The MFA quantifies the fluxes of different materials through a defined space, within a certain time. An MFA system is defined by a system border, processes, goods/materials and fluxes of goods/materials between the different processes. Data on fluxes are obtained empirically (e.g. from market surveys) or from literature. The proportion of the fluxes out of a specific process is defined by transfer-coefficients (Baccini and Brunner, 1991; Baccini and Bader, 1996). The MFA was also used by Leitzinger (Chapter 4.2 this volume). For data used in the case of Tunja see Binder (1996), URPA (1995), and Alba Gonzales *et al.* (1998).

Results and Discussion

MFA for the municipality of Tunja

We selected the political border of the Municipality of Tunja as the system border for our analysis. The system consists of two subsystems, rural Tunja and urban Tunja; and a total of nine processes and 21 goods. The urban sub-system includes the processes 'Market Place' and 'Supermarket', which supply the city with food; 'Consumers' who consume the food and either dispose of waste in 'Landfill', or have their excreta transported to the 'Surface Water'. The rural sub-system includes two agricultural processes: 'Cattle Breeding/Milk Production' and 'Plant Growth and Management' (arable agriculture). Respectively two separate soil compartments are selected: 'Pasture Soil' and 'Agricultural Soil'. Figure 4.1.1 presents the MFA for organic dry matter (DM)¹ calculated for the year 1993.

Urban sub-system

Supermarket and Market Place supply the consumers in Tunja with food at 60% and 40%, respectively. About 50% of the total food demand of Tunja is covered by local production, i.e. rural Tunja is able to satisfy the demand for food in urban Tunja as follows: for tubers completely, for cereals to a degree (about 70%) and for meat at about 30%. The rest has to be imported. Due to overproduction, Tunja also exports potatoes. In the overall analysis, Tunja

¹Organic carbon $\times 1.724$ = organic matter.

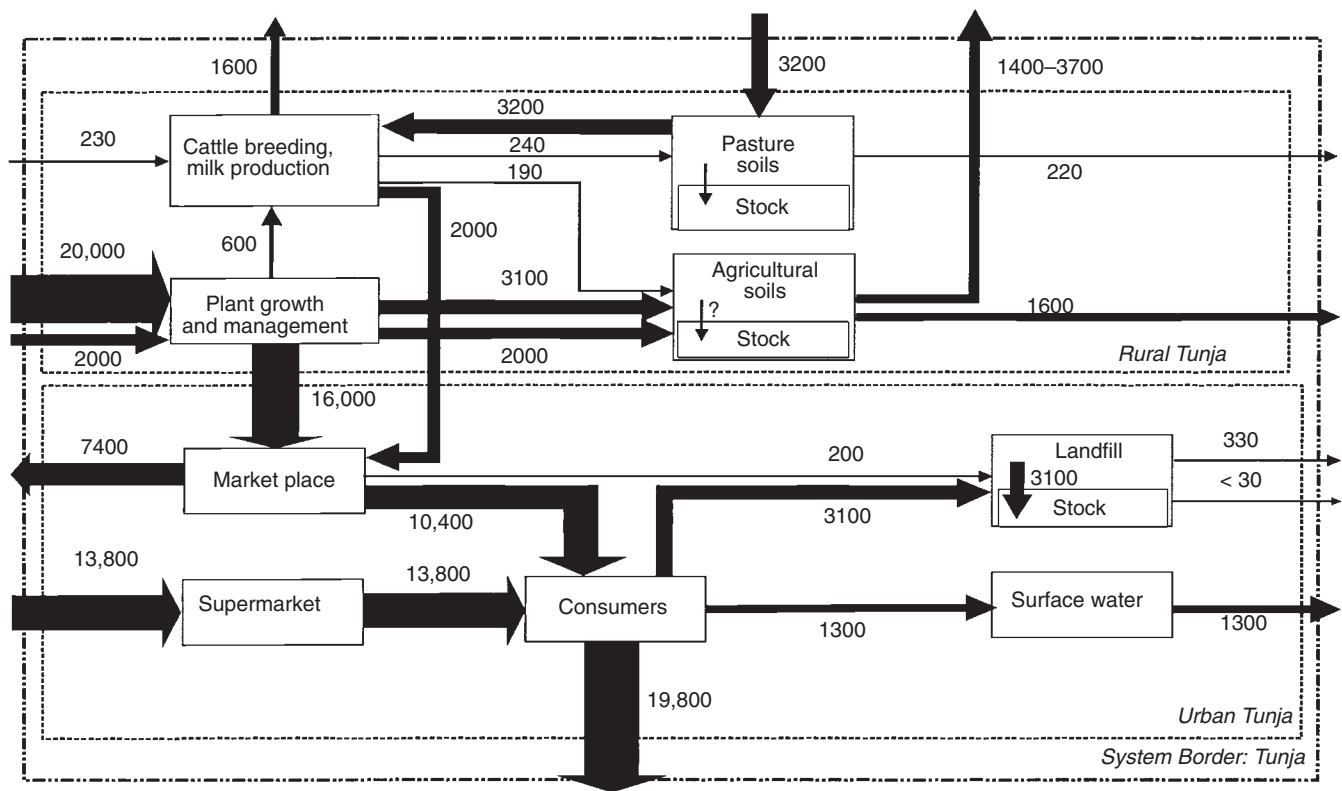


Fig. 4.1.1. Fluxes of dry matter for the municipality of Tunja (t DM year⁻¹). Root biomass is not included. Box balances may not add up because of rounding.

has a net import of about 6400 t DM year⁻¹ (26% of total consumption) in order to satisfy the food demand of its inhabitants.

With regard to carbon, the largest C amount of the consumed food is emitted in the form of CO₂ through respiration. Of the organic waste produced by consumers 70% of the DM is solid waste (3100 t DM year⁻¹), which is deposited in the Landfill. The other 30% are excreta, which are transported without treatment to the Surface Water. The Market Place also generates solid organic wastes, which make up for about 6% of the total solid organic waste generated in urban Tunja. On the landfill site carbon is lost as CH₄ and in leachates.

Rural sub-system

The largest fluxes in the rural area are CO₂ import for the photosynthesis process. In the process Plant Growth and Management, about 20,000 t DM are produced, of which 80% are agricultural products traded in the Market Place. The other 20% are plant residues (3700 t DM year⁻¹). According to Alba Gonzales *et al.* (1998) 84% of these residues are left on the soil and 16% are collected for feeding farm animals. The flow of plant residues to Agricultural Soils is equal to the flow of organic waste from Consumers to the Landfill. For plant production (mostly potatoes), mineral fertilizer is imported.

Cattle breeding is sustained to a large extent by the pastures. Fodder and nutritional supplements are imported to complement cattle growth. Via cattle dung, some nutrient cycling is performed in the Pasture Soil. According to Alba Gonzales *et al.* (1998), farmers collect about 44% of the cattle dung to use it on their agricultural fields. However, compared with the other DM fluxes, cattle dung at 190 t DM year⁻¹ is only about 6% of the total input of DM into agricultural soils.

Potential Organic Carbon Sources

Based on the flow of DM and its high correlation with the flow of organic carbon, one can determine two main potential sources for supplying organic carbon to soils: plant residues (3100 t DM year⁻¹) and urban organic wastes (solid at 3300 t DM year⁻¹ and liquid at 1300 t DM year⁻¹). In the study region (which is a rather dry region), 84% of the plant residues are left on the field and incorporated into the soil when ploughing for the next season (Alba Gonzales *et al.*, 1998).

For health reasons, organic wastes from the urban area, have to be treated before they are applied to agricultural soils (Cross and Strauss, 1985). Solid organic wastes, such as food residues, are composted, while excreta, the liquid organic fraction, can be treated in different ways (Table 4.1.1). During the treatments, the total amount of organic carbon in these goods is reduced by half or even more.

Table 4.1.1. Organic carbon in residues after different treatments of urban organic wastes.

Practice ^a	Organic carbon in residue (%)
Solid organic waste treatment	
Composting	40
Excreta treatments	
Sewage treatment	30–35
Night-soil composting	50
Co-composting	50

^a For details see Binder and Patzel (1999).

Potential Carbon Recycling for Rural Areas

Figure 4.1.2 shows the potential carbon-flux for the Municipality of Tunja with improved waste treatment (root biomass is not included in the analysis). The average error margin of the data lies between 10 and 20%. Three main conclusions can be drawn:

1. The total input flux into Agricultural Soils is $2440 \text{ t C year}^{-1}$. It lies between 1 and 2% of the organic carbon stock in these soils.
2. The organic carbon supply within the rural area itself (with $1400 \text{ t C year}^{-1}$) is about twice the potential input of organic carbon after treatment from the urban area ($920 \text{ t C year}^{-1}$). In other words, there is already a large potential of organic carbon supply in the rural area itself. The contribution of organic carbon via cattle dung ($120 \text{ t C year}^{-1}$) is an order of magnitude smaller than the contribution through plant residues.
3. The potential carbon contribution from urban areas is in the same range as the estimated C-losses through erosion (at $700 \text{ t C year}^{-1}$). Thus, applying treated organic wastes from the urban areas to agricultural soils could compensate the loss of organic matter through erosion.

Possible Application Rates

The total amount of organic carbon (including rural wastes) that could potentially be distributed over the whole agricultural area is about $520 \text{ kg C ha}^{-1} \text{ year}^{-1}$ (Table 4.1.2). Considering losses of about 50% through waste collection and distribution, for example the yearly organic carbon flow to Agricultural Soils may range between 260 and $520 \text{ kg C ha}^{-1} \text{ year}^{-1}$, which corresponds to an application rate of about $3\text{--}6 \text{ t compost ha}^{-1} \text{ year}^{-1}$ wet weight².

²Assuming 45% C content in dry weight and 80% water content in waste.

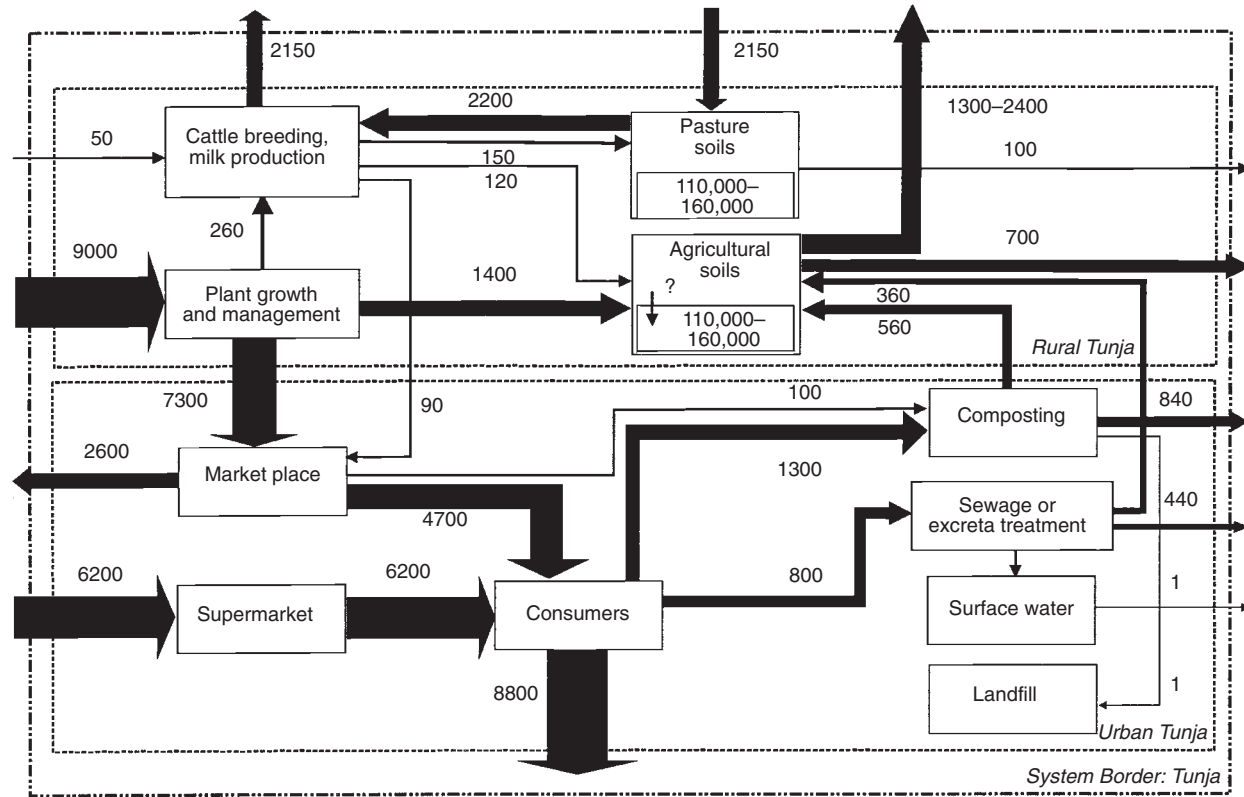


Fig. 4.1.2. Carbon-flux for the municipality of Tunja with improved waste treatment (in t C year⁻¹). Root biomass is not included. Box balances may not add up because of rounding.

Table 4.1.2. Potential organic carbon flows from urban and rural organic wastes into agricultural soils.

	Carbon flow into soil (t C year ⁻¹)	Amount per arable ha for total area (kg C ha ⁻¹ year ⁻¹)	
		Max	Min
Urban area			
Compost	560	120	60
Treated excreta ^a	360	77	38
Rural area			
Plant residues ^b	1400	300	150
Animal dung ^c	120	25	13
Total	2440	522	261

^a We assume that about 55% of the C content of excreta is transformed to CO₂ before it is brought out to the field.

^b We assume here that only the parts of the crops that are sold leave the field.

^c Values refer to untreated dung.

With recommended application rates of at least 20 t compost ha⁻¹ year⁻¹ and 10–30 t ha⁻¹ of night-soil composted with organic waste, only parts of the land can receive compost. Thus, one has to consider that there is a conflict between allocation needs and allocation costs. The distribution will be further determined by farmers' willingness to pay for the product, and their social acceptance of urban wastes as fertilizer.

Conclusions

This chapter shows that:

1. In the municipality of Tunja, with an arable area of 47 km² and a population of 114,000 inhabitants, the potential for supplying agricultural soils with organic matter is largest for organic wastes produced in its rural areas. Organic wastes originating in the urban area amount to 37% of the total potential carbon flow into agricultural soils.
2. The compost produced in urban areas can quantitatively compensate carbon losses through erosion but not balance additional losses due to organic matter decomposition. The farmers in need of compost are those who cultivate the erosion-prone slopes of the valley. However, they are usually poor farmers who may not have the means to pay for related transport costs.

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4.2 The Potential of Co-composting in Kumasi – Quantification of the Urban and Peri-urban Nutrient Balance

C. Leitzinger

Entsorgung + Recycling Zürich (ERZ), Zürich, Switzerland

A material flux analysis was used to study the fate of organic matter (carbon), nitrogen and phosphorus in the rural–urban nutrient cycle of Kumasi, Ghana. The assessment included market and consumption surveys, and an estimate of the amounts of organic wastes available and that could enter the co-composting process taking into account the actual collection capacity of the waste management authority. Finally, the amount of nutrients that could theoretically be reintroduced into the nutrient cycle has been estimated.

Key words: West Africa, Ghana, composting, food consumption, urban agriculture, nutrient balance, carbon, nitrogen, phosphorus, material flux analysis

Introduction

The discussion of the benefits of nutrient recycling, for example through an integrated urban waste management strategy, requires hard data on the kind and amount of waste generated and its fertilizer value. In other words, it is interesting to analyse the fate of the nutrients entering a city in the form of food items, etc., or in more academic terms the study of nutrient fluxes. The work presented here summarizes corresponding results of Leitzinger (2000). Using the material flux analysis (MFA) the research focus was on the estimation of the quantities of organic matter and nutrients available for co-composting in Kumasi, Ghana. The study was carried out in the frame of a joint project of ETH (Swiss Federal Institute of Technology) and EAWAG/SANDEC (Swiss Federal Institute for Environmental Science and Technology/Department of Water and Sanitation in Developing Countries) in collaboration with IBSRAM-Africa.

The study took place in Kumasi, the capital town of Ashanti Region, Ghana, with a total population of about 0.98 million inhabitants on an actual area of about 223 km². Kumasi is endowed with industries/production sectors (such as breweries, sawmills, poultry farms) and important regional markets. There are also about 1468 registered farmers in the city as well as some 30,000 backyard gardens (Kumasi Metropolitan Assembly, 1996; KNRMP, 1999; MOFA, 1999).

The sanitary situation of Kumasi is rather precarious (Salifu, 1990) despite a range of different sanitary facilities, such as public toilets, bucket latrines, WC/septic tanks, sewerage and pit latrines. The collected faecal sludge is treated in a faecal sludge-treatment plant in Kaasi near Kumasi that has been operating since February 1999 (Leitzinger and Adwedaa, 1999). Residential solid waste is collected via 124 waste transfer stations that are spread over the city. Due to lack of infrastructure, waste is collected weekly or bi-weekly, mostly from community containers.

For this study the following questions were posed:

- How large are the nutrient fluxes from urban or peri-urban agriculture or from outside these boundaries into the city of Kumasi?
- Through which processes/activities do these nutrients flow? What are the transfer coefficients of C, N and P in these processes/activities?
- How many wastes could theoretically enter the co-composting process?
- What is the realistic quantity of compost that can be produced in Kumasi?
- How many nutrients could be reintroduced into the nutrient cycle?

This pilot study did not address the economic, legal or sociocultural aspects of the subject, but tried to consider logistic and technical aspects. However, economics, financing (investment, running costs), and marketing are important issues to be considered. From the sociocultural point of view it would be important to study to what extent the agricultural sector is ready to use compost as fertilizer, i.e. its social and cultural acceptance by the farmers. With regard to the technical and logistic aspects, the experience of Accra (cf. Etuah-Jackson *et al.*, Chapter 3.2 this volume) tells us that the technique should be simple to use and maintain. Finally, this study did not consider the potential heavy metal content of the compost, which can be an important concern to its use and marketability.

Methodology

A MFA with *SIMBOX*[®] simulation was applied. MFA is a method used to describe and analyse the flux of different materials through a defined space and within a certain time (Baccini and Bader, 1996; Binder and Patzel, Chapter 4.1 this volume). From the results important sources, sinks and nutrient transfers can be discovered. The value of the output depends largely on data quality and knowledge of the involved processes (physical, biological and chemical). Despite these requirements, the MFA is flexible enough for application in developing countries (Binder, 1996).

An MFA helps in early detection of resource needs and can indicate environmental degradation as a result of human activities. The method covers the following four steps:

1. System analysis of the activities and goods.
2. Determination of the mass fluxes of all the goods per unit of time and the concentrations of the selected elements in these goods.
3. Calculation of the mass and element fluxes from the mass fluxes of goods and element concentrations in these goods.
4. Interpretation and presentation of the results.

An MFA system is defined by an artificial system border, processes, goods/materials, and fluxes of goods/materials between the different processes. The term 'process' denotes the transport, transformation or storage of materials and goods. In this study, the different processes concern mostly urban and peri-urban agriculture, agroproduction activities (sawmills, breweries, poultry farms), supply activities (markets), the individual households with solid and human waste and waste disposal (faecal sludge treatment plant and landfill). These processes are within the system border while environmental sinks such as 'atmosphere' or 'surface waters (and/or soils)' are placed outside the system border. The administrative boundary of Kumasi is chosen as the system border but the process 'peri-urban agriculture' is included¹. Fluxes were calculated on the basis of our surveys and transfer coefficients. These coefficients describe how much of a certain good is transferred from one process to another (as usually parts are lost).

For data evaluation, visualization and error estimation, *SIMBOX*[®], a simulation programme for material and energy fluxes in an 'anthropogene' system was used. More information on this programme can be found on the EAWAG homepage (www.eawag.ch/services_e/software/e_simbox.html).

For the quantification of organic goods such as foodstuffs, charcoal, wood, fodder, market waste, household wastes (solid and human waste), different approaches were used for data collection and comparison, sometimes different approaches were used for the same goods. This internal control (e.g. food market survey vs. consumption survey) proved worthy for data quality. In most cases primary data were compiled, e.g. through market and consumption surveys, but also via interviews at breweries, sawmills, poultry farms, etc. Related data provided by Nsiah-Gyabaah and Adam (Chapter 3.3 this volume) were used for comparison. Where available, secondary data from the city administrations, ministries or veterinary services etc. were incorporated.

¹Urban agriculture refers here to the Kumasi Metropolitan Area, peri-urban agriculture to the area between the urban area and a circle with a radius of 40 km from the city centre (Blake and Kasanga, 1997).

Results

Actual biomass and nutrient fluxes

With the help of the MFA, important nutrient fluxes between urban, peri-urban, and rural agriculture were quantified and qualified. Figures 4.2.1, 4.2.2 and 4.2.3 show the actual flows of carbon, nitrogen and phosphorus. The results reveal that the key process contributing to the organic material fluxes is 'private households', as they are characterized by a large turnover of materials and large waste production.

Consumption and waste generation

A consumption survey covering 440 people in 91 households and 215 people for street food revealed that the 'average' person consumes annually 766 kg of food² (at home and as street food) without consideration of food consumption from their own production; 2.1 kg per head day⁻¹ largely consists of 'fufu' (cassava, plantain, meat/fish, garden eggs (aubergines)), the major and if possible daily dish in this region. While backyards contribute about 5% to urban food consumption (KNRMP, 1999) the MFA estimates that in total urban agriculture contributes about 14% of the household food requirements. Assuming that peri-urban agriculture serves first of all Kumasi, then up to 66% of the household food demand is supplied by peri-urban agriculture, while 20% has to come from outside the system border, i.e. mostly from rural areas. The MFA error margin is about 25% of each absolute figure.

Usually, the advantages of urban agriculture are related to its contribution to urban food supply with perishable products. However, including major staple crops such as yams, cassava, plantains and maize, which constitute about 50% of the overall consumption, urban and peri-urban agriculture can provide substantial amounts. The surveys showed with respect to these four crops, that 12% of their supply on the markets derives from urban agriculture. About 35% is supplied by peri-urban agriculture and 53% comes from rural areas (e.g. all the yams).

Kumasi's households produce in total about 255,000 t of solid waste year⁻¹. Kumasi's markets about 53,000 t year⁻¹. While the market waste is collected on a daily basis, the current capacity of the Waste Management Department can maximally address about 110,000 t of household waste. Of the small amounts of collected and treated night-soil about 7700 t of settled sludge are available for co-composting as well as about 10,000 t of wood shavings and sawdust, which constitute only a small part of the total amount of waste produced in the Kumasi's timber processing industry. In addition,

² The data are estimated with an error margin of 20%. The figure concerns the food items as bought, i.e. including peels and natural water content. The survey considered about 20 food items, but not food imported to Ghana with the exception of wheat, rice, and potatoes.

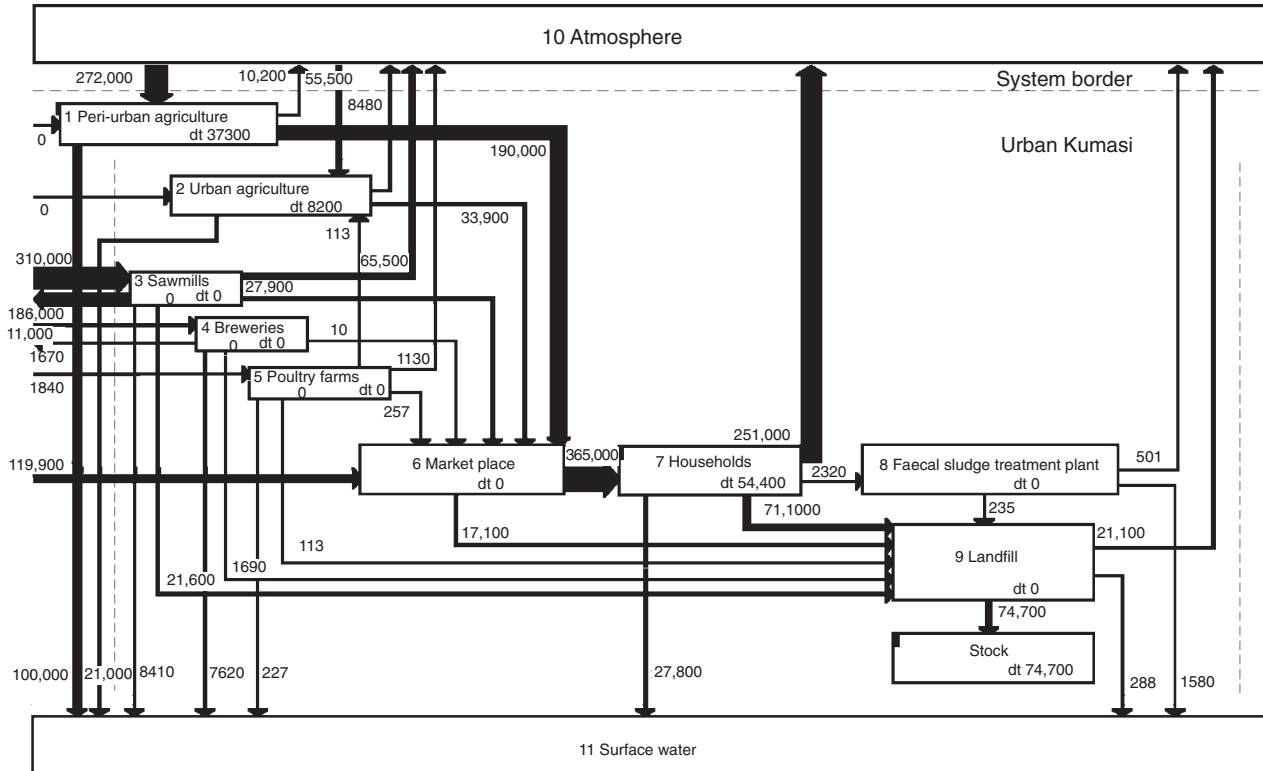


Fig. 4.2.1. Visualized C fluxes in t year^{-1} . In the present situation there is a C loss of c. 8200 t year^{-1} in urban agriculture and c. $37,000 \text{ t year}^{-1}$ in peri-urban agriculture. There is only a very small amount of C recycled in the order of c. 110 t year^{-1} from poultry farms to agriculture. Carbon is mostly lost as CO_2 (dt in the boxes (= processes) means: change in store in t year^{-1}).

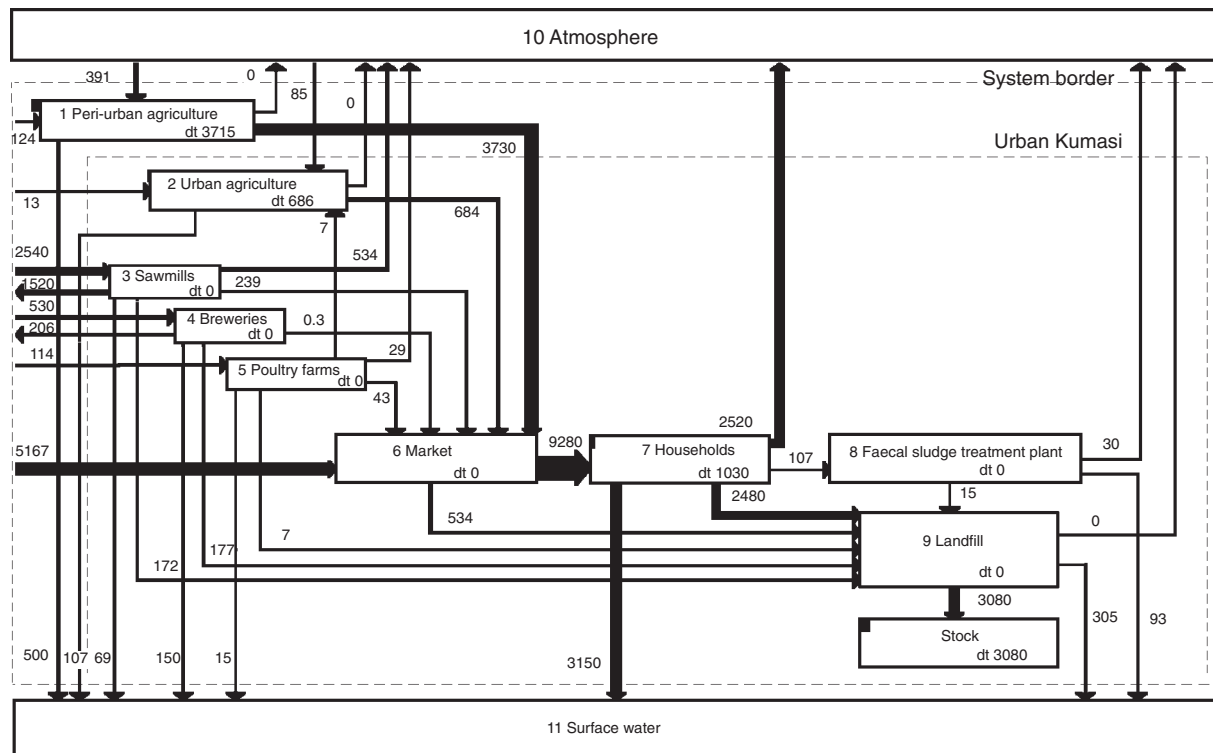


Fig. 4.2.2. Visualized N fluxes in t year⁻¹. In the present situation there is an N loss of c. 680 t year⁻¹ in urban agriculture and c. 3700 t year⁻¹ in peri-urban agriculture. Nitrogen is lost for re-use in approximately the same proportions via the atmosphere, surface water and landfill.

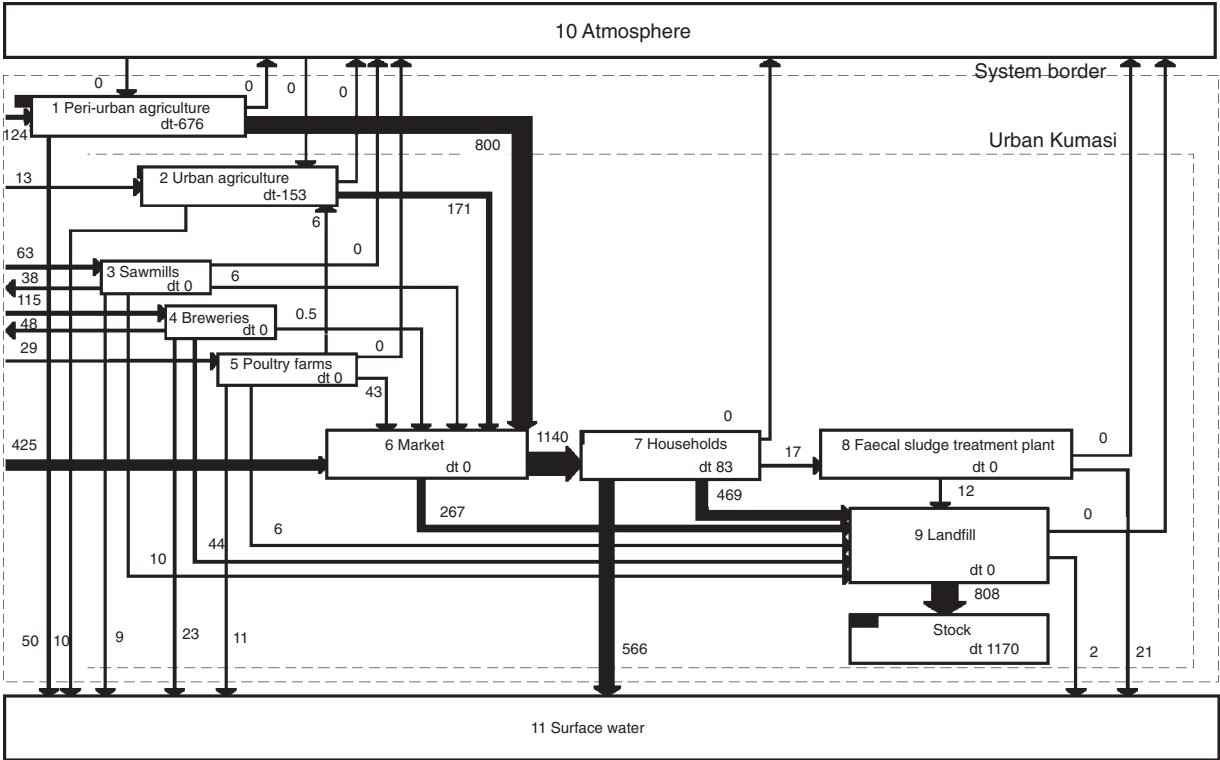


Fig. 4.2.3. Visualized P fluxes in t year^{-1} . In the present situation there is a P loss of c. 150 t year^{-1} in urban agriculture and c. 680 t year^{-1} in peri-urban agriculture. The P flux from agriculture goes approximately in the same proportion into surface water and landfill, where it is lost.

about 5000 t of organic waste could be added from commercial poultry farms and Kumasi's breweries. These estimates have an error margin of 20–25% (Leitzinger, 2000).

Scenarios with co-composting

From the theoretical composition of the different waste-stream products available in Kumasi, their water content, and C:N ratio, it should be possible to produce quality compost (cf. Soo-Saeng, 1981; Cross and Strauss, 1985). The biodegradable organic fraction of Kumasi's solid waste is estimated to reach 90%, however, the percentage is changing slightly with a steady increase in plastic and rubber components.

Figures 4.2.4, 4.2.5 and 4.2.6 show the results of an MFA with respect to the C, N and P fluxes in a scenario with a co-composting component (of faecal sludge with solid waste) on the basis of the actual collection and transport capacity of the Kumasi Waste Management Department. The scenario is assuming only changes in the destination of the waste transport and the existence of related co-composting facilities.

The analysis shows that it would be possible to cover the C, N and P demand³ of urban agriculture and in addition 30% of the C, 13% of the N, and 25% of the P demand of peri-urban agriculture in the 40 km radius of Kumasi. That means, even with co-composting, soil nutrient mining in peri-urban Kumasi will still occur, while for urban agriculture the nutrient cycle could be closed. To guarantee sustainable soil fertility management in the peri-urban area there is still the need for inorganic fertilizer. However, it is noteworthy that the amounts of N and P, which could be provided through co-composting, are higher than the total amount of N and P supplied through inorganic fertilizer in the whole Ashanti Region.

Moreover, as many soils are P deficient, the high proportion of P recycling makes the co-composting option very interesting.

A sensitivity analysis carried out to determine how quantity and composition of the compost would change under different input scenarios showed that the results depend largely on the C:N:P ratios of the input goods and their weight. Here, household and market wastes are the most significant contributors as shown above.

Conclusions and Recommendations

Material flow analysis allows us to identify key processes for resource recovery in the urban–rural context. In the case of Kumasi, private households are the key process for organic material, nutrient fluxes, and waste generation, and

³Demand comprises the estimated loss of soil nutrients through crop uptake and leaching/runoff.

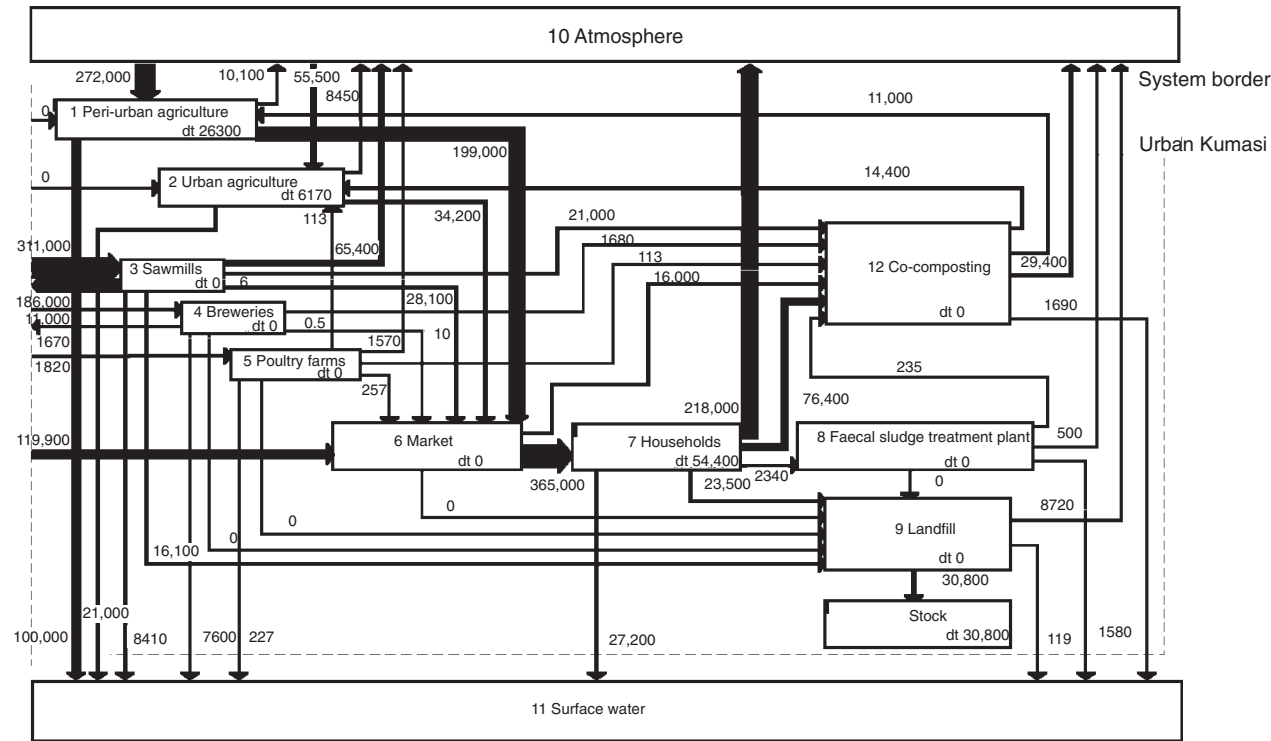


Fig. 4.2.4. C fluxes in t year^{-1} with co-composting. In a possible future situation with co-composting more than 100% (c. 14,400 t year^{-1}) of the carbon (biomass) loss in urban areas (c. 8200 t year^{-1}) and 30% (c. 11,000 t year^{-1}) of the 37,000 t year^{-1} loss in peri-urban areas could be recycled. In fact, there would be a surplus of carbon for urban agriculture with respect to the amount of recycled nitrogen, which just covers the N loss (see Fig. 4.2.5).

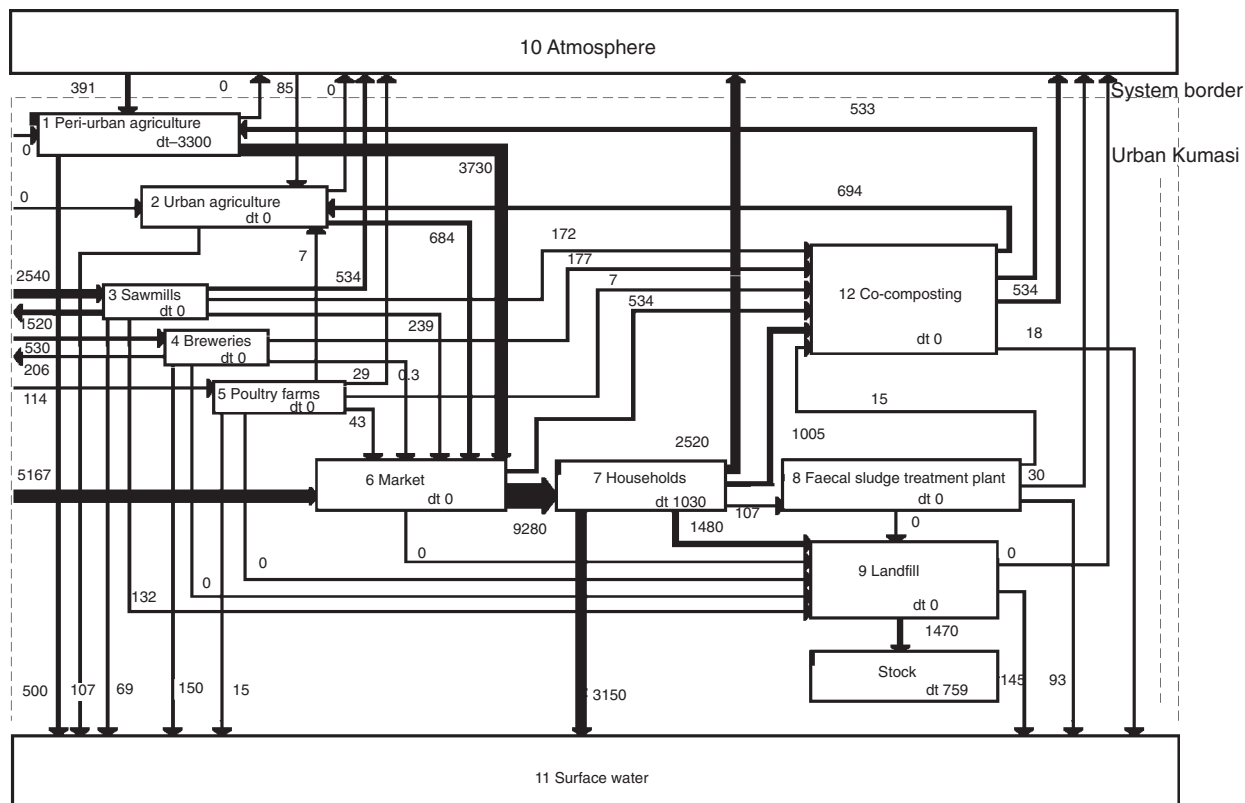


Fig. 4.2.5. N fluxes in t year^{-1} with co-composting. In a possible future situation with co-composting 100% (c. 690 t year^{-1}) of the N loss in urban areas and 13% (c. 530 t year^{-1}) of the loss in peri-urban areas could be recycled for agricultural production.

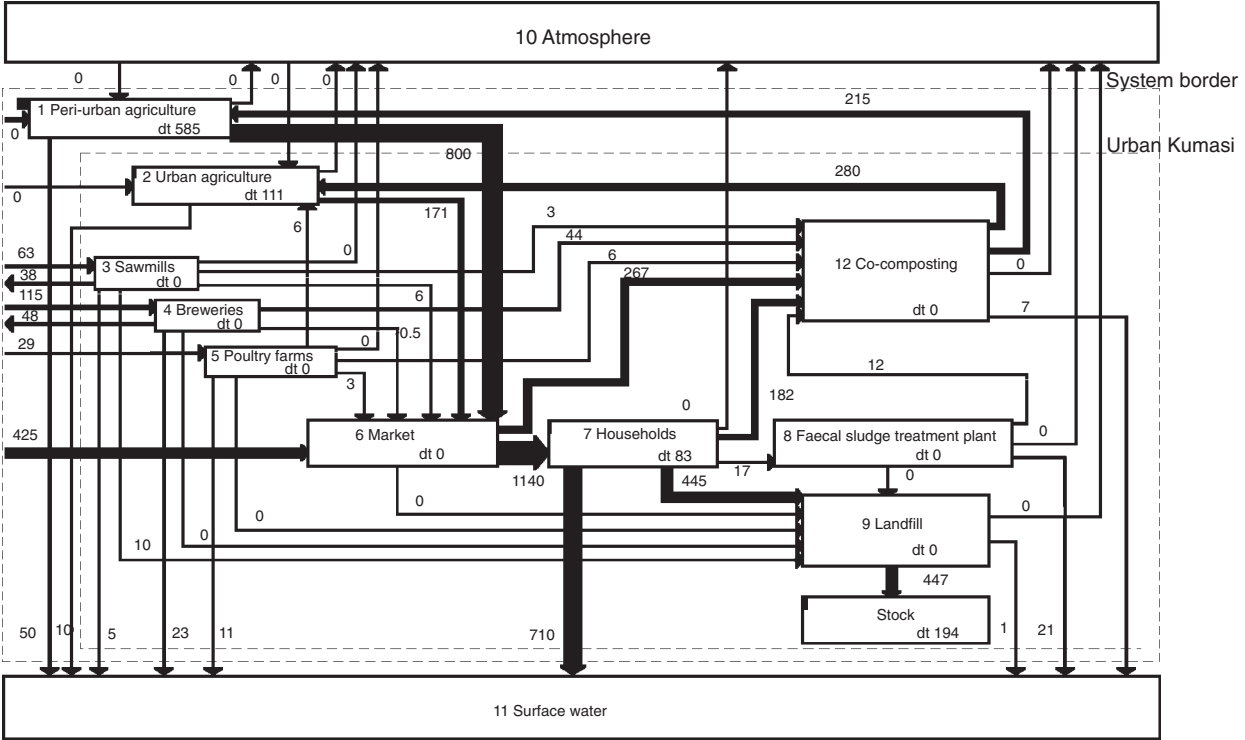


Fig. 4.2.6. P fluxes in t year^{-1} with co-composting. In a possible future situation with co-composting more than 100% (c. 280 t year^{-1}) of the loss in the urban area and 25% (c. 530 t year^{-1}) of the loss in the peri-urban area could be recycled for farming purposes.

measures for resource recovery should start here. Additional organic waste-stream products are generated by the local industry (sawmills, poultry farms, breweries) and in Kumasi's markets.

From the technical point of view, all the currently collected faecal sludge in Kumasi could theoretically be co-composted without any additional treatment plant; the pollution of soils and surface water with faeces could be reduced simultaneously. It can be concluded that from the amount of waste available the potential for co-composting in Kumasi is very high.

Solid waste management is a multidisciplinary activity that involves not only engineering principles. Current follow-up studies by IWMI (formerly IBSRAM) to consider also the economic, legal, sociocultural, logistic and technical aspects that were not treated in the current study (i.e. of waste generation, on-site storage, collection, transfer and transport, processing and recovery, and disposal of the solid waste from the society). There will be special focus on feasibility studies to discover the costs (investment, running costs) involved in the co-composting process and related marketing aspects to access whether there are enough buyers, i.e. farmers' willingness and ability to pay for the product has to be studied.

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4.3 Estimating Rural–Urban Nutrient Flows for Mega-cities

J. Færge¹, J. Magid¹ and F. Penning de Vries²

¹Department of Agricultural Sciences, Royal Veterinary and Agricultural University, Frederiksberg, Denmark; ²IWMI (formerly of IBSRAM), Bangkok, Thailand

To explore the potential for recycling of nutrients ‘wasted’ in mega-cities, a nutrient balance model mostly based on secondary, statistical data was developed. The magnitude of nutrient flows (N, P) into and out of the city was established for Bangkok Province, Thailand, indicating large losses into its central river.

Key words: South-East Asia, Thailand, nutrients, food supply

Introduction

The world population increases currently by about 80 million a year and is expected to reach about 9 billion by 2050. At the same time an increasing part of the total world population will live in urban areas, in which half of the total population of the current 6 billion was expected to live by the turn of the century (UN, 1998). Concomitantly, the cities, and especially expanding mega-cities must cope with rapidly increasing amounts of waste causing health problems as well as detrimental impacts on the environment (WRI, 1996).

A large part of this waste is organic and contains nutrients that could be re-used for food production. To explore the potential of nutrient recycling, a first approach could be the quantification of the actual nutrient flows into and out of cities (Drechsel *et al.*, 1999). The nutrient balance can give a maximum estimate of the amount of nutrients remaining in the city as well as of possible sinks. Such estimates could give useful indications for example in comparison with data on nutrient mining and fertilizer demand in rural or peri-urban production areas. The aim of the present study was to elaborate a model for an urban nutrient balance assessment, suitable for mega-cities, based on secondary data.

Elaborating a nutrient balance for mega-cities, such as Bangkok in our case, and surrounding areas is rather complex, as shown by Newcombe (1977) for Hong Kong. Many flows of nutrients can only be estimated indirectly. In our case, the final balance covers Bangkok Province, not the city alone, as most statistical data were only available for the provincial level, while other (e.g. on waste collection) refer to the city area. The balance is made for 1996, as more recent statistical data were not available.

A Nutrient Balance for Bangkok

In 1996, the population of Bangkok Metropolitan Area was around 5.6 million and about 9 million in the larger Bangkok Metropolitan Region (NSO, 1997). Bangkok Metropolis has a total area of 1565 km² of which 21.6% (339 km²) is used for farming. The Bangkok plain is mainly derived from the delta of the Chao Phraya River and most of it consists of dark grey clay, which is very suitable for paddy rice. However, silt and sandy loams, suitable for vegetables, can be found close to the river and its tributary banks. Of the farm land, 73.6% is used for paddy rice, 10.2% for fruit trees, 4.6% for vegetables, 0.6% for field crops, and others (11.2%) (MOAC, 1998a).

The rural–urban nutrient cycle

Initially, the model aimed to address nitrogen, phosphorus and potassium. However, during elaboration of the balance, it was found that the data base for potassium was insufficient.

Figure 4.3.1 shows a general picture of nutrient flows into and out of urban and peri-urban areas. Nutrient flows to Bangkok will to a great extent be a function of demand for food. Consequently, population size and demand per capita is decisive in estimating the nutrient inflow from the consumption side. However, some of the purchased food is produced locally in Bangkok and therefore does not cause nutrient inflows, except for fertilizer or animal feed import. Nutrients are also deposited from the atmosphere. In urban areas, especially deposition of N, caused by combustion of fossil fuels, is of interest. On the other hand, the magnitude of P-deposition is small compared with its inflow via food, feed and fertilizer. In the balance the atmospheric deposition of P is considered insignificant and was not taken into consideration.

It follows that the inflow of nutrients to Bangkok is defined as the sum of nutrients in all food, feed and fertilizer entering the city plus atmospheric deposition of N. In other words with respect to food consumption, the inflow of nutrients comprises all food supplied for human consumption but if we add nutrients in feed and fertilizer then we have to deduct locally produced agricultural products (cf. Fig. 4.3.2). This definition has the advantage that it does

not matter whether agricultural products produced in Bangkok are consumed locally or outside the city.

The outflow of nutrients from Bangkok is more elusive to estimate than inflow. Food is either eaten or disposed of as food waste, resulting in an outflow of nutrients as either solid waste or sewage and night-soil sludge. Part of this finds its way through run-off into streams and canals (in Thai: *klongs*) and the Chao Phraya River. In addition nutrients are also accumulated in soils and sediments including fish ponds (cf. Edwards, 1993) or lost to the atmosphere.

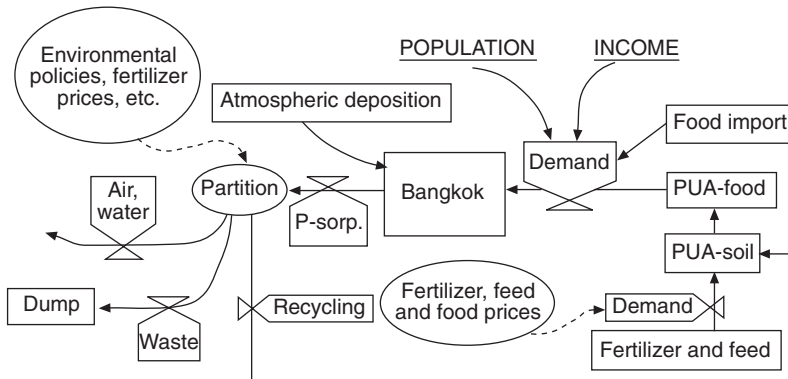


Fig. 4.3.1. Relational diagram of nutrient flows into and out of Bangkok. Population and income are driving variables, determining the overall supply of food and thereby most of the inflow of nutrients. In addition to food, nutrients are deposited from the atmosphere too. The flow of nutrients from Bangkok is the same as inflow minus a P fraction, which is adsorbed. After decomposition of the food, the nutrients are partitioned between volatile gases, dumped waste and recycling.

Rectangles represent quantities (state variables); valve symbols: flows (rate variables); circles: auxiliary variables; underlined variables: driving and other external variables; full lines: flows of material; dotted lines: information flow. PUA, peri-urban and urban agriculture.

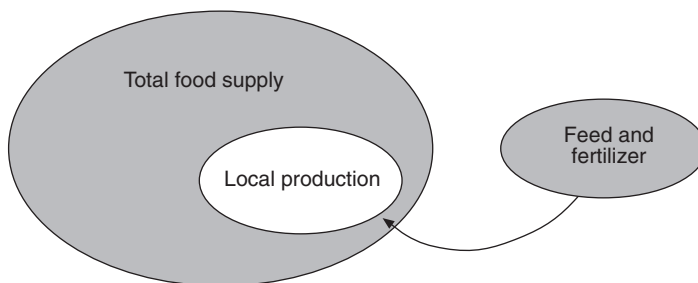


Fig. 4.3.2. Food, fodder and fertilizer flow to Bangkok. Total nutrient inflow is defined as the sum of nutrients in all food supplied for human consumption minus nutrients in locally produced agricultural products plus nutrients in feed and fertilizer as well as atmospheric deposition of N (deposition not included in the figure).

To estimate the outflow of nutrients, data exist for solid waste collection and for sewage/night-soil sludge. Data also exist for the water quality of the Chao Phraya River, from which it is possible to estimate the extra-load of N and P from the city. However there is no data on (eventual) accumulation of nutrients in soils and sediments. Therefore this sink (in addition to any other unaccounted flow/sink) can only be estimated as the difference between total inflow and outflow. Nitrogen lost to the atmosphere through denitrification and burning of waste was ignored due to lack of consistent data.

Food supply to Bangkok

An estimation of the average food supply to the population of Thailand can be found in the online FAOSTAT data base (FAO, 1999). However income in Bangkok is higher than elsewhere in Thailand (NSO, 1997) and conventional wisdom indicates that food consumption is income dependent (World Bank, 1986). Therefore it appeared necessary to make an adjustment for this disparity, although the discussion on this issue is ongoing (cf. Behrman and Deolalikar, 1987; Bouis, 1994; Dawson and Tiffin, 1998). In comparison with data provided by Dawson (1997) it is argued that an income elasticity of about 0.05 probably will account for extra calorie demand in Bangkok compared with the average demand in Thailand. As the average per capita product in Bangkok is calculated to be 3.4 times the average national product (cf. NSO, 1997), a correspondingly higher income is assumed. To sum up, the total supply of food to Bangkok was computed from the number of inhabitants and average national food supply data, was augmented by 17% according to higher income in Bangkok than the average in Thailand.

The adjustment for income on total supply of calories does not consider that diet composition is income dependent, too (Jussaume, 1998; Rae, 1997, 1998). The consumption of non-cereal products such as meat, fish, and vegetables generally increases as income grows. However it is important to keep in mind that the task here is not to estimate the food flow of different food commodities but to estimate the inherent nutrients in the food. During the 1980s the increase in consumption of livestock products was small in Thailand compared to most other East Asian countries (Simpson *et al.*, 1994). Moreover, the relative increase in total calorie and total protein supply in Thailand was almost similar between 1965 and 1996 (FAO, 1999). Therefore, changes in diet were not taken into consideration.

The total food supply to Bangkok in 1996 is shown in Table 4.3.1. The total amount of protein in the food is 121,530 t, which, with a conversion factor of 0.16 between protein and N, is equivalent to 19,445 t N. The content of P in beef, eggs, milk, pork and poultry, is calculated to be 1121 t (cf. Beveridge, 1987; Scherz and Senser, 1994). Fish constitutes 73% of all the seafood. To simplify, a general value for P in fish is used for all seafood.

Table 4.3.1. Food supply to Bangkok in 1996 (in t). The amount of food, estimated from FAOSTAT (FAO, 1999) is augmented by 17% according to the higher purchasing power in Bangkok compared to the average in Thailand.

Foodstuff	Amount	Foodstuff	Amount	Foodstuff	Amount
Vegetable products		Palm kernels	300	Vegetables, other	162,100
Apples excl. cider	3,500	Peas	300	Wheat	73,400
Bananas	150,800	Pepper	1,100	Wine	900
Barley, beer	82,000	Pimento	2,900	Animal products	
Barley – excluding beer	400	Pineapples	130,700	Animal fats	5,100
Beans	16,700	Potatoes	2,900	Aquatic animals, other	500
Beverages, fermented	1,700	Pulses, other	12,000	Beef and veal	27,200
Cassava	23,400	Rape and mustard seed	100	Cephalopods	12,300
Cocoa beans	1,800	Rice (milled equivalent)	707,400	Crustaceans	18,800
Coconuts – incl. copra	85,200	Roots, other	11,000	Demersal fish	20,000
Coffee	1,100	Sesame seed	300	Eggs	62,100
Fruit, other	238,600	Soybeans	9,100	Freshwater fish	28,900
Grapefruit	1,400	Spices, others	1,800	Marine fish, others	4,500
Grapes – excl. wine	3,000	Sugar (raw equivalent)	193,700	Milk, excl. butter	146,800
Groundnuts	8,700	Sugar cane	32,100	Molluscs, other	13,900
Honey	100	Sugar, non-centrifugal	700	Mutton and goat meat	100
Lemons, limes	8,000	Sweet potatoes	8,800	Offal	6,000
Maize	2,200	Tea	700	Pelagic fish	66,800
Oil crops, others	500	Tree nuts	4,900	Pork	32,500
Onions	25,000	Tomatoes	9,300	Poultry meat	87,900
Oranges, mandarins	101,000	Vegetable oils	34,500		

Depending on soil fertility and fertilization the content of nutrients in vegetable products is highly variable. However, for standardization purposes/procedures an average N:P ratio of 10 was assumed (cf. Walworth and Sumner, 1987) which, however, does not include soybean with a much higher ratio due to nitrogen fixation.

Given a N:P ratio of 10 and estimations for the content of protein in the food (FAOSTAT), it is possible to estimate the total amount of P in plant products. However, because of the paramount importance of rice (with 0.185% P) in the diet in Thailand, and thereby for the nutrient balance, the P content in rice was assessed separately.

In total, the amount of N and P in the food supplied to Bangkok is estimated to be 19,445 t N year⁻¹ and 2918 t P year⁻¹, respectively.

Inner-city Food Production

Food production in Bangkok is, as previously mentioned, dominated by paddy rice, but production of freshwater fish is also important, covering 40% of the total supply. Table 4.3.2 shows the total production in 1996/97. The amount of N and P in the food is calculated as mentioned for the food supply. The total amount of N and P in food produced in Bangkok is calculated to be 1995 t N and 306 t P, respectively. Data were taken from MOAC (1998a,b,c, 1999) as well as the Ministry of Agriculture and Cooperatives (unpublished). The nutrient content was calculated from Scherz and Senser (1994) and Beveridge (1987).

Fertilizer use

In general the record of fertilizer use in Thailand is not good (PCD, 1997). The data for the total use of fertilizer in Thailand is only available without provincial distinction (MOAC, 1998a). However 73.6% of the farm land in Bangkok is cropped with paddy rice and MOAC (1998b, 1998c) presents data for the provincial use of fertilizer. From these data it can be calculated that the average application of fertilizer per hectare to paddy rice in Bangkok is 1.74 times more than the average use in Thailand. Assuming that farm-land not used for paddy, is also allocated 1.74 times more fertilizer than the average in Thailand, the total use of industrial fertilizer in Bangkok (in 1996) can be estimated to be 2064 and 564 t of N and P respectively, which is equivalent to an average allocation of 61 kg N and 17 kg P ha⁻¹ year⁻¹.

Nutrients in feed for animal husbandry

Freshwater fish culture is according to Table 4.3.2, the most important animal produce in Bangkok and subsequently for the balance it is important to estimate the use of fish feed accurately. Unfortunately, no corresponding secondary data could be found.

For an indirect estimation of the amount of feed it is necessary to know whether the production is extensive, intensive or somewhere in between. If extensive, the pond, lake or rice field, used to rear the fish, will produce all the feed. But if the production is intensive, regular feed is allocated. Semi-intensive systems, are fed with supplementary feed and/or pig and poultry manure for example (Edwards, 1993).

Nutrient conversion ratios for N and P of intensive fish production are highly dependent on the ratio of feed conversion, i.e. the ratio between fish feed and produced fish. Where pelleted feed is used intensively the feed conversion ratio is about 1.5:2 (Boonyaratpalin, personal communication). Assuming an average of 1.75, the nutrient conversion ratio for N and P will be in the order of 3.3 and 6.2, respectively (Edwards, 1993).

If the freshwater fish and shrimp production in Bangkok is aggregated and the average feed conversion ratio is anticipated to be 1.75, the N and P inflow in feed for aquaculture can be estimated to be 1031 and 257 t year⁻¹ respectively. However, this estimate refers to an intensive production solely supplied with industrial feed. In Bangkok, however, fish is mainly reared in semi-intensive ponds with all kinds of fodder: industrial feed, food waste as well as pig and chicken manure. Therefore the real inflow must be lower. But, failing to estimate the actual amount, this maximum estimate was used in our model.

Anticipating a nutrient conversion ratio, between feed and produce of 5 (N) and 10 (P) for the rest of the animal produce, we get an estimated additional inflow of 1207 and 186 t year⁻¹ of N and P, respectively.

To sum up, the N and P in the feed used in Bangkok is estimated to be 2238 and 443 t year⁻¹ respectively.

Nutrients in waste

In Bangkok, about 80% of the generated solid waste is collected (Muttamara *et al.*, 1993). In 1996 wastewater and night-soil treatment, on the other hand, were provided for an average of only about 2 and 19%, respectively, of the population (Stoll and Parameswaran, 1996; DPC, 1997). The amount of food waste, sewage and night-soil sludge and the estimated nutrients therein can be seen in Table 4.3.3. Data on N and P content in sludge was taken from AIT (1995), food waste data from DPC (1997). Nutrients in food waste were estimated to be 25% of the average content in the food supplied.

Table 4.3.2. Food produced in Bangkok in 1996 (in t).

Foodstuff	Amount	Foodstuff	Amount
Rice	119,304	Broilers	4,859
Beef (cattle, buffalo)	202	Eggs	3,671
Freshwater fish	11,553	Milk	1,225
Shrimps	656	Fruit	45,851
Pork	231	Vegetables	27,752

Table 4.3.3. Amount of food waste, night-soil and sewage sludge from Bangkok and the amount of N and P in waste as well as N and P per hectare if recycled to Bangkok's farmland. The table further shows the recovery fraction of nutrients (see text).

Waste type	Amount	N	P
Night-soil sludge (t year ⁻¹)	10,300 ^a	283	103
Sewage sludge (t year ⁻¹)	2,086	20	6
Food waste (t year ⁻¹)	620,000	1,120	168
Total waste (t year ⁻¹)	–	1,423	277
Recovery (%)		7	9
Bangkok (kg ha ⁻¹)		42	8

^a Solid dry matter amount estimated from 395,304 m³ night-soil collected (DPC, 1997) and a conversion factor at 0.13 between raw night-soil and sludge, producing a sludge at 20% dry matter (Stoll and Parameswaran, 1996).

The table also shows the apparent recovery of nutrients in waste, as the ratio of nutrients in waste to the nutrients in total food supply. The table further shows that if all the collected waste were recycled to agricultural soil in Bangkok, the allocation per hectare of N and P on average would be 42 kg and 8 kg, respectively.

Nutrients discharged to the aquatic environment

The Pollution Control Department in Thailand (PCD, 1997) has established 32 water quality stations along the Chao Phraya River and conducted 18 water quality surveys from 1988 to 1997. Part of the water quality programme is measurements of N and P. The content of N and P in water samples near the river mouth is about 1.3 and 0.08 mg l⁻¹, respectively, higher than the content of N and P in the water station at Nonthaburi near the upstream border of Bangkok. The average outflow of water from the Chao Phraya River is given with about 590 m³ s⁻¹. From these data (ignoring eventual denitrification as well as P-sorption processes) the load of N and P from Bangkok to the Chao Phraya River is estimated to be about 24,200 and 1490 t year⁻¹, respectively. This load certainly derives from waste water and sewage but also contains a P fraction from washing detergents, which were not considered as inflow.

(Un)certainity of estimations

Most of the estimations used for the present nutrient balance are heavily dependent on literature-based values (e.g. for nutrient content in food, feed conversion ratios, etc.). Depending on the source, the result may vary considerably, as sensitivity analyses showed.

Accepting the supply data, provided by national statistics or re-processed by FAO, the most important source of deviation is the nutrient content in the food and particularly in the major one, which is rice (cf. Table 4.3.2). On the other hand, the estimate on fertilizer use to non-paddy land is of minor impact for the total balance. If for instance, factor 3 instead of factor 1.74 were used, it would only increase the N and P supply by 15% through this (minor) channel, i.e. by 316 and 84 t year⁻¹, respectively.

The nutrient outflow, mainly consisting of collected waste and discharge to Chao Phraya River, as well as the data on waste collection are based on empirical surveys/analyses, thus sources of error are limited to data collection. With regard to data from the Chao Phraya River, averages for several years were used to increase reliability. However, the magnitude of N discharge is very high in relation to all other inflows and outflows and other (industrial) sources of river pollution with N should be assessed. A cross-check of the nutrient contents measured in the waste with default values from Tchobanoglous (1991) did not reveal major deviations.

To sum up, and with regard to the quantities involved, the most important factor in the nutrient balance, after accepting the food supply data from FAO-STAT, is the nutrient content of rice.

As the variability in P content (0.1–0.27%) is much higher than the variability of N content (0.97–1.36) the sensitivity analysis was only calculated for P. Using either the minimum or the maximum estimate for P content, the estimated 707,400 t of rice supplied to Bangkok per year, would expand the estimated amount of P from 707 to 1909 t year⁻¹. To be on the safe side and with respect to the correlation between fertilizer use and plant nutrient content, it was judged that the rice consumed in Bangkok has an average P content of around 0.185%.

Nutrient Balance and Discussion

Summarizing the different estimations for inflows and outflows of nutrients we get inflows of 821 t N and 1850 t P in excess of their respective outflows (Table 4.3.4). In other words, the outflows of N and P are found to be respectively 97% and 51% of the respective inflows. Thus, the model can account for nearly the total loss of nitrogen, partly through massive discharge into the Chao Phraya River¹. With respect to P, half of the inflow is not accounted for. Some of it might be accumulated in agricultural soils, but a much larger part is supposed to be accumulated in the *klongs*, fish ponds and wherever organic waste is in contact with soil. As the P load of the Chao Phraya River will contain P from laundry detergents, which were not considered as inflow, the unaccounted P fraction will be larger than the figure given in Table 4.3.4.

¹N accumulated in human protein of a growing population might be in the order of 150 t year⁻¹, thus negligible (assessed via the population number and growth rate, the body weight increase per year, and the average nitrogen content in human body of 3.5%).

Table 4.3.4. Nutrient balance for Bangkok (t year^{-1}).

	Nitrogen	Phosphorus
Inflow		
Food supply	19,445	2,918
Fertilizer	2,064	564
Feed	2,238	443
Deposition (estimated as 30 kg ha^{-1})	4,695	n.d.
Food production	1,995	306
Total inflow	26,447	3,619
Outflow		
Waste	-1,423	-277
Chao Phraya River	-24,200	-1,490
Total outflow	-25,623	-1,767
Balance (In-Out)	+824	+1,852

Waste water and night-soil treatment covered in 1996, as mentioned above, only 2% and 19% of their respective generation in Bangkok. According to a Masterplan for Bangkok (AIT, 1995) it is intended to establish 10 central waste water treatment plants and four night-soil treatment plants to treat about 42% and 50% respectively of the waste water and night-soil generated. The expected amount of waste water (sewage) – sludge and night-soil sludge from these plants are respectively 36,500 and 2550 t year^{-1} of dry matter (Eckhardt and Khatiwada, 1998). Table 4.3.5 shows the actual nutrient recovery fraction (NRF) in relation to the total amount of nutrients in food, and the NRF in case the Masterplan is implemented, as well as for a scenario that all sewage and night-soil is collected. The table further shows the expected application rates of N and P per hectare assuming nutrient recycling from waste for agricultural use in Bangkok Province.

Table 4.3.5 shows that actually only a small fraction of nutrients is recovered from the amount of N and P in the total food supply. And even in the best scenario the NRF would be only 19% for N and 35% for P. The corresponding potential for recycling would be 106 and 30 $\text{kg N and P ha}^{-1} \text{ year}^{-1}$.

Table 4.3.5. Nutrient recovery fractions (NRF) of nutrients in relation to the total amount of nutrients in food calculated for three scenarios (see text). The table further shows the amount per ha of N and P if the waste were recycled to fertilize Bangkok's soils.

NRF from waste water and night-soil	N recovery (%)	P recovery (%)	kg N ha^{-1}	kg P ha^{-1}
Current situation (cf. Table 4.3.3)	7	9	42	8
Masterplan	12	19	68	17
All households	19	35	106	30

Outlook

The present model alleges that total food demand in cities can be estimated using the FAOSTAT data base, city population data, and some adjustments. However, the data show that there is still much need for fine-tuning to improve and validate the model. Also actual measurements of food flows have to be carried out. Moreover the parameterization of the model (nutrient content in food, N-deposition, etc.) revealed data gaps, which have to be closed. To ameliorate the parameterization, studies regarding the nutrient content in food and food waste, feed/fertilizer use in aquaculture and urban atmospheric deposition of N should be executed. Moreover, the different sources of river pollution have to be quantified.

However, independent of the data gaps, the study shows that huge amounts of nutrients are lost from Bangkok Province into the river (and the sea). These losses can be attributed to insufficient sewage treatment. By increasing the nutrient recovery fraction from different types of waste, there is a high potential for nutrient re-use in urban and peri-urban agriculture.

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4.4 Monitoring Nutrient Flows and Economic Performance in African Farming Systems: the *NUTMON* Approach and its Applicability to Peri-urban Agriculture

H. Van den Bosch¹, D. Eaton², M.S. Van Wijk²,
J. Vlaming¹ and A. De Jager²

¹Alterra Green World Research, Wageningen, The Netherlands; ²Agricultural Economics Research Institute (LEI), The Hague, The Netherlands

In this chapter the different phases of the NUTMON methodology to analyse nutrient flows and balances for farming systems are described as well as the possibilities of application of the methodology in the context of peri-urban agriculture. The farm diagnosis tool NUTShell was used to link nutrient flows with economic flows.

Key words: East Africa, Kenya, nutrients, farming systems, urban agriculture

Introduction

In sub-Saharan Africa (SSA) rural farm households, developers and policy makers increasingly recognize soil nutrient depletion as one of the major constraints to a sustainable agricultural and rural development (Smaling *et al.*, 1996). Farm households are confronted with deteriorating relative price relations between farm outputs and inputs and increased land pressure, resulting in a net exploitation of soil nutrients. Given the socio-economic environment, farm households have limited options for investments in nutrient-adding or nutrient-saving techniques, which have been developed in many research centres or are known to farmers already. It is obvious that the complex problem of profitable and sustainable nutrient management requires more than most of the currently ongoing, monodisciplinary, monoscale and scattered research activities can offer. It is therefore necessary to integrate different relevant disciplines and scales, and at the same time to disentangle the

various issues into a workable set of problem statements for targeting research and development.

In contrast to rural agriculture, urban and peri-urban agriculture refers to 'food production activities taking place within and on the periphery of cities and towns' (Ellis and Sumberg, 1998). The difficulty in formulating a more precise definition arises from the lack of clear boundaries between rural, peri-urban and urban farming situations. Perhaps the feature of most interest in peri-urban systems is their focus on production for urban markets (Midmore, 1995). Thus these farming systems are more commercially oriented than rural systems and are characterized by a greater degree of intensification due to the higher returns to farm products resulting from the low transport costs to major markets. This proximity to cities permits the intensive cultivation of highly perishable products (on a year-round basis) such as vegetables. Peri-urban systems, defined as such, are particularly dependent on transport corridors. Of course, these systems also include aspects of rural systems, such as staple cereal crops. Indeed, an important characteristic of urban and peri-urban agriculture systems is their diversity within relatively confined geographical limits. Much attention has been paid to vegetable production but intensive animal farming systems are also very common (see for example, Mbiba, 1995; Ouedraogo and Zoundi, 1999). In African farming systems, though, it is the intensified use of inputs in urban and peri-urban production systems to produce higher value products, particularly vegetables, that is the main difference in comparison with rural farming systems (Drechsel *et al.*, 1999).

The soil nutrient issues of interest in peri-urban agriculture are thus somewhat different from those usually discussed in the context of African farming systems. Intensive horticultural production is based on irrigation and the regular addition of inorganic and organic nutrient sources. The supply of mineral fertilizers is more reliable in and around major urban centres while at the same time the higher value end-products support a greater use of these purchased nutrients. Organic nutrient sources are locally available in large amounts on a fairly regular basis (in comparison with many rural farming systems). Thus, the availability of macronutrients is less likely to be a major constraining factor on crop production. In a sector with such rapidly occurring changes (well described, for example by Ellis and Sumberg, 1998) the efficient management of inorganic and organic nutrient additions, as well as irrigation practices, are of greater importance as soil fertility issues. However, it may still be the case that the increased addition of nutrients may not be enough to compensate for uptake and thus soil nutrient depletion may also be occurring. But this depletion may not always be a matter of concern if peri-urban land use is changing so constantly due to rapid urban growth. Whether nutrient availability in the intensified systems is a constraining factor remains an issue for further research, the gradual transition between peri-urban and rural farming systems means that the ability to make the jump to the next level of intensive nutrient inputs is always an issue for some.

The nutrient interaction between cropping and animal production systems is also an issue of interest in peri-urban agriculture, and there is also the possibility of recycling large amounts of organic waste, easily available in the vicinity (see for example, Kouvonou *et al.*, 1999). Another perspective on nutrient flows in peri-urban agriculture might look at the mesoscales and macroscales of interactions between the urban and peri-urban zones on the one hand, and the rural zone on the other. For example, a substantial net inflow of major nutrients from the rural to the urban and peri-urban zones can be expected (Drechsel *et al.*, 1999). It may also be the case, though, that the most significant net flow occurs from the peri-urban to the urban zone (raising the difficult issue of how far the peri-urban zone extends).

NUTMON aims at the development of a comprehensive multidisciplinary methodology, which is targeted at the different factors dealing with the management of plant nutrients in tropical agriculture. Farm monitoring takes place at plot and farm household level, since most of the decisions concerning nutrient management are taken at that level. Influences of processes at lower scales (for example, factors determining leaching) and higher scales (policy instruments influencing farm management decisions) are studied as well and incorporated in the farm level approach. Three major phases can be distinguished:

1. Diagnosis of existing farm and nutrient management;
2. Participatory integrated nutrient management (INM) technology development through on-farm trials;
3. Development of policy instruments.

The diagnostic phase aims to analyse the current nutrient management, determine the magnitude and major sources of nutrient depletion, analyse the economic performance, create farm households awareness of nutrient management aspects, and jointly with the farm households, arrive at a research and development agenda. The farm and enterprise nutrient balance can serve as a sustainability indicator with respect to soil fertility. The quantified flows and balances and the economic analysis, resulting from this diagnostic phase are the basis for targeting, planning, and implementation of on-farm INM trials (Phase 2) and scenario studies concerning policy instruments (Phase 3) to facilitate adoption of INM. Farmers, extensionists, non-governmental organization (NGO) staff, researchers and policy-makers are involved in this planning and implementation process. The diagnostic step was applied in the *NUTMON* pilot project in Kenya (De Jager *et al.*, 1998a,b; Van den Bosch *et al.*, 1998a,b) and some of the results are discussed hereafter. However some aspects of the concept, such as inventory of policy instruments and participatory soil and nutrient flow mapping, have only been implemented recently in ongoing field projects and are therefore described in more global terms. This also applies to the methodology for INM technology and policy development phases.

In this chapter the three phases of the *NUTMON* methodology are described ('The *NUTMON* Approach'). A more detailed description of the concepts and methodologies used in Phase 1 (farm level analysis of nutrient flows and farm economy) is given in 'Concepts of the Farm Diagnostic Tool:

NUTShell. 'Results from Application in African Farming Systems' gives examples of results to be obtained with *NUTMON*, and 'Applicability of *NUTMON* to Peri-urban Agriculture' discusses the possibilities of application of the *NUTMON* methodology in the context of peri-urban agriculture.

The *NUTMON* Approach

Phase 1: Diagnosis

Study areas are selected according to priorities set by government policies, agro-ecological settings or according to available research infrastructure or resources. To classify the complex and heterogeneous situation at the mesoscale, various land-use zones (LUZs) are identified. Use is made of: (i) geographical maps; (ii) agro-ecological zone maps; (iii) land-use maps of the district; (iv) recent satellite images and air photos to adjust boundaries of the major land-use zones; (v) secondary information collected within the area on crops and livestock diversity and distribution; and (vi) participatory rural appraisal (PRA) including transect walks by multidisciplinary teams of researchers and extension staff. Through PRA farm types are identified within each LUZ, differentiated according to: (i) topography; (ii) sizes; (iii) production level; (iv) management level; (v) level of input use; (vi) the level of resource endowment; and (vii) socio-economic characteristics.

Within each farm, different enterprises are identified for the determination of nutrient flows (Van den Bosch *et al.*, 1998b). A diagnosis exercise starts with resource flow mapping (RFM, Defour *et al.*, 1998) and discussions with farm households on soil nutrient management. After this, a farm inventory (identifying the major features of the farm and serving as a framework for the monitoring phase) and a monitoring exercise (quantifying the nutrient flows and economic flows to and from all farm units) are carried out. The inventory is conducted at the start and end of each monitoring year. Monitoring usually takes place each month but may also have a lower intensity if farming systems are not too complex or if areas have only one major growing season. Questionnaires include the following major information categories: inputs in fields and livestock, outputs from fields and livestock, average confinement of the animals, re-use of manure and household waste, growth of herd, inputs and outputs to and from the food stock, family labour and off-farm income. Additional secondary information is collected to enable the calculation of nutrient and economic flows, such as nutrient contents of plant, animal products, manure and compost, prices of inputs and outputs, etc.

The results of the quantification of flows and the economic parameters are discussed and validated in a workshop between the participating farm households, extensionists and research staff. This participatory diagnosis is then followed by discussions focusing on formulating priorities for testing and developing INM technologies in the different farm types and LUZs (Deugd *et al.*, 1998).

The diagnosis phase was carried out in the *NUTMON* project (Phase 1, three districts in Kenya, 1994–1996) and results of this study are presented in ‘Results from Application in African Farming Systems’ in this chapter (page 183).

Phase 2: Participatory INM technology development

Based on the results of the diagnostic phase, the most appropriate technologies for a specific farming system are identified. Flow maps, quantified flows, nutrient balances and economic parameters are used to select and target nutrient management techniques. For existing techniques on-farm trials are planned and implemented by farmers to test and adapt these techniques in a participatory learning process. At the same time, on-station trials may be conducted for testing new ideas or not yet very well developed technologies. The planning of a new cycle of experiments depends upon the results of monitoring of the trials and the learning process of the farm households. The proposed approach combines traditional farming systems’ approaches (Norman and Collinson, 1986; Tripp and Woolley, 1989) with more recently developed participatory technology development (PTD) and farmers’ learning concepts (Chambers *et al.*, 1989; Reijntjes *et al.*, 1992). Currently a *NUTMON* project (LEINUTS) is being carried out dealing with participatory development of INM techniques. Results are not yet available.

Phase 3: Inventory of relevant policy instruments

Policy (instruments) affect adoption of alternative technologies (Barrett, 1991; Lutz, 1992; Holden and Shanmugaratnam, 1995). In workshops with relevant policy-makers, alternative policy instruments are discussed and formulated. Testing the impact of these policies is done through pilot projects (for instruments such as credit schemes, input procurement, marketing systems etc.), simple model simulations and stakeholders’ interviews (for price and market interventions). For the identified INM technologies, recommended policy instruments to facilitate adoption at a wide scale are formulated and discussed with relevant stakeholders.

Concepts of the Farm Diagnosis Tool: *NUTShell*

The farm diagnosis tool (*NUTShell*) combines nutrient flow quantification with an economic analysis of the farming system, allowing nutrient mining to be related to the economic performance of the farm. The integration of economic and biophysical analysis also makes it possible to evaluate the economic, financial and labour-related possibilities, and constraints of adoption and implementation of alternative INM strategies, aiming at more efficient nutrient use.

NUTShell is a tool that encompasses different stages in farm analysis: data gathering, data storage and checking, data manipulation (in this case calculation of nutrient stocks and flows and calculation of economic performance parameters) and presentation of the results. It includes a structured questionnaire, a database and simple models to quantify flows. The tool calculates flows and balances of the macronutrients N, P and K and is based on a set of five inflows (mineral fertilizer, organic inputs, atmospheric deposition, biological nitrogen fixation, sedimentation), six outflows (farm products, other organic outputs, leaching, gaseous losses, erosion and human excreta), and six internal flows (consumption of external feed, household waste, crop residues, grazing, animal manure, and home consumption of farm products). The flows are shown in Fig. 4.4.1.

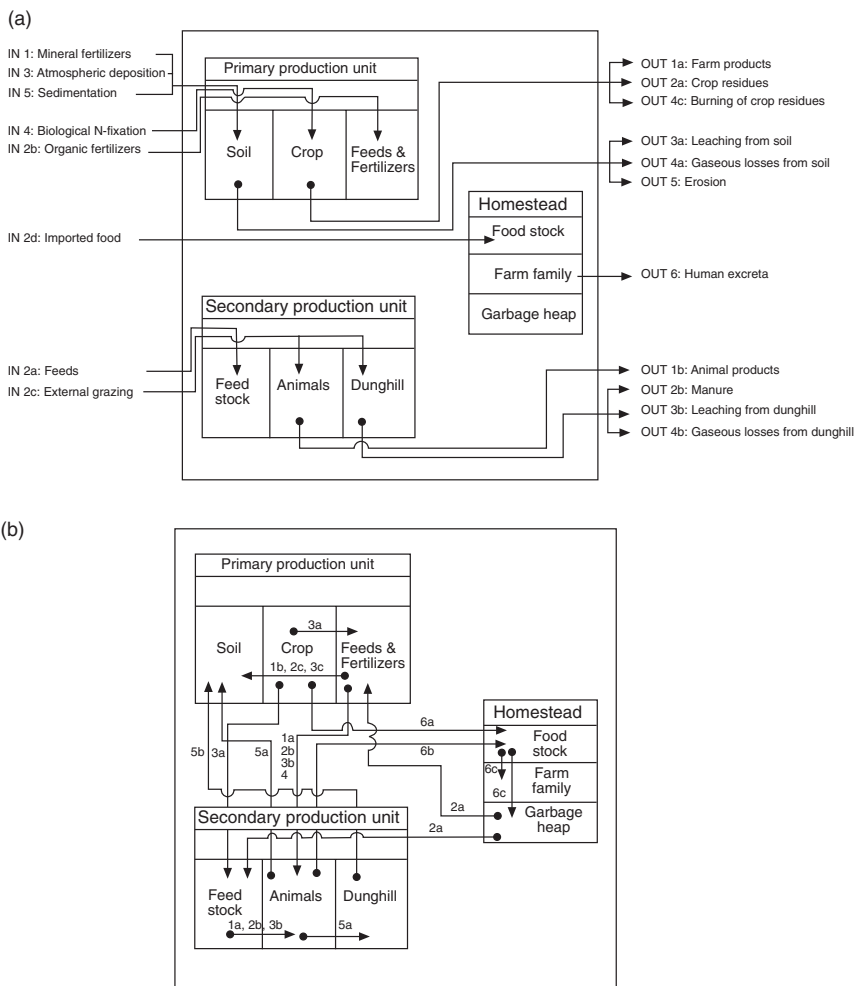


Fig. 4.4.1. Farm concept with its units, flows (a) into and out of and (b) within a farm.

Farm concept

The farm concept is shown in Fig. 4.4.1 (farm compartments, inflows, outflows and internal flows). Within this farm concept, five types of compartments are defined: primary production compartments (fields with crops, pasture, fallow or farmyard), secondary production compartments (livestock groups), redistribution units (manure heaps, compost pits, etc.), stocks and the household. Three types of nutrient flows are distinguished: flows into the farm, flows out of the farm, and flows within a farm between compartments.

Approaches to quantifying flows

Basically, three methods are used to quantify the nutrient flows: (i) asking the farmer; (ii) use of transfer function; and (iii) other approaches using sub-models and assumptions. Van den Bosch *et al.* (1998a) gives a detailed description of the methods used for nutrient flow quantification.

Method 1 (asking the farmer)

This method, based on information from the questionnaire, is used for the flows IN 1, IN 2 a, b, d, OUT 1, OUT 2, FI 2a, FI 3a, FI 5b and FI 6. The farmer usually quantifies the product flow in local units that are converted into SI-units by means of conversion factors. Absolute amounts of N, P and K in the flow are calculated using the nutrient contents of the nutrient carrier.

Method 2 (use of transfer functions)

Transfer functions are used to estimate those nutrient flows for which the information cannot be given by the farmer or obtained by simple measurements. They are used to estimate flows IN3, IN4, OUT 3, OUT 4 and OUT 5. Transfer functions are simple relations that explain difficult-to-quantify variables as a function of easily obtainable parameters, such as mean annual precipitation and clay content of the soil. The functions are derived by curve-fitting using data gathered from the literature.

Method 3 (other approaches)

Simple models or calculation rules are used to quantify flows related to feed consumption and manure excretion by livestock. Biological N-fixation (IN 4a) is estimated by using a crop-specific percentage of the total N uptake by symbiotic N-fixation.

Economic calculations

A similar farm concept is used for the economic calculation procedures in order to be able to link the nutrient flows to the economic flows. The results can be

divided into two groups: (i) farm household characteristics; and (ii) performance indicators at farm and activity levels. Van den Bosch *et al.* (1998a) provide a complete listing of the results. Performance indicators are distinguished at the activity level and at the farm level (Dillon and Hardaker, 1993). At activity level, economic performance indicators are calculated only for the primary and secondary production compartments. Cash flow measures (involving actual cash transactions) and income and profitability measures (involving cash and imputed values or opportunity costs and benefits) are calculated at both levels, since both the cash flow and the economic performance are relevant to farm household decisions concerning soil nutrient management.

Monetary values are attached to the quantified nutrient flows that are a direct result of farm management activities (IN 1, IN 2, OUT 1 and OUT 2). Nutrient inflows by, for instance, deposition and biological nitrogen fixation and outflows such as leaching and gaseous losses are not considered in the economic performance calculations. In the analysis, however, attempts are made to estimate the economic values of nutrient losses (De Jager *et al.*, 1998b). The calculation of economic performance indicators also involves inflows and outflows other than those of nutrients, for instance labour input, pesticides, animal traction, etc. This leads to a different classification of inputs and outputs, which is more geared towards an economic analysis. At the activity level, gross margins and cash flows per compartment are calculated, both for primary and secondary production compartments.

Economic performance at the farm household level is measured as net farm income. This indicator measures the reward to the farm family for its labour and management and the return to all the capital invested in the farm, whether borrowed or not. The total income available to the farm family is calculated as the total family earnings, which includes the net farm income plus any other household income. At the farm level, a number of more specific performance indicators are calculated for the sum of the primary and secondary production compartments, as well as the returns on invested capital, family labour and land.

Results from Application in African Farming Systems

Three different districts in Kenya (Kisii, Kakamega and Embu) were selected for the fieldwork, representing a wide range of soils, climates, and socio-economic and ethnic settings. For each district, LUZs were defined and PRAs were conducted to identify the different farming systems and one or two farms were selected in each LUZ. A farm inventory was carried out to identify major nutrient pools and flows. Over a full year, farmers were interviewed about nutrient management and the economic situation of the farm. Crop products and residues were sampled on all farms. Meat, milk and the most common external inputs were sampled on farms and local markets. Samples were analysed for total N, P and K.

Farm level analysis

Two different balances were defined. The partial balance at farm level ($IN\ 1 + IN\ 2 - OUT\ 1 - OUT\ 2$) is made up solely of primary data and mainly reflects the 'way of farming'. The full balance, defined as $(IN\ 1\ to\ IN\ 4) - (OUT\ 1\ to\ OUT\ 6)$, is a combination of the partial balance and the immissions (atmospheric deposition and nitrogen fixation) and emissions (leaching, gaseous losses, erosion losses and human excreta) from and to the environment.

Partial balances

The mean partial balances of the 26 farms amounted to +34 kg N, +12 kg P and +27 kg K $ha^{-1}\ year^{-1}$. This means that farmers imported more nutrients through fertilizers than were exported through sale of products. Nutrient inflow through chemical fertilizers was highest in the Embu farms, due to considerable use of P fertilizer in the cash crops tea and coffee on the higher slopes of Mount Kenya. A striking aspect is the overall negligible import of nutrients through organic fertilizer: of the 26 farms, 24 did not purchase any organic fertilizers. Outflow of N through crop products, i.e. farm products that leave the farm and that are not used for home consumption, averaged 11 kg N $ha^{-1}\ year^{-1}$, with Kakamega at a lower level of 5 kg N $ha^{-1}\ year^{-1}$. This was confirmed by the lower market orientation of Kakamega farms (De Jager *et al.*, 1998b) as compared to Embu and Kisii. Nutrients leaving the farm through the export of crop residues or through manure were recorded at one farm only.

The full balances amounted to -71 kg N, +3 kg P and -9 kg K $ha^{-1}\ year^{-1}$, which means that the positive partial balance was turned negative because of high nutrient losses in the systems. The sum of the emissions was much higher than the sum of the immissions. Total immissions, defined as the sum of atmospheric deposition (IN 3) and biological nitrogen fixation (IN 4), made up 8% of the total inputs at the farm level. Total emissions, defined as the sum of leaching (OUT 3), gaseous losses (OUT 4), erosion (OUT 5) and human excreta (OUT 6), made up 86% of total outputs.

Three groups of market orientation are distinguished: < 33%, 33–66%, and > 66% of the gross revenues sold. In Table 4.4.1 the averages of the most relevant farm characteristics are presented. Subsistence-oriented farms (< 33%) have a significantly less negative nutrient balance for N and K than market-oriented farms (> 66%). The partial balance for N is positive in all three groups, but the inflow through fertilizers increases with the market orientation. Inflow through organic sources on the other hand decreases with the market orientation due to higher occurrence of zero grazing management (less outside grazing and feeding on farm-produced napier grass) and lower total number of livestock. It should be realized that on the subsistence-oriented farms, the nutrient balance is relatively positive through the process of concentration of nutrients from grazing land to the cultivated lands. The

sustainability of the system is therefore related to the grazing to arable land ratio and increasing land pressure may lead to a decline of this ratio. The market orientation is related to intensification of the farming system: capital and labour-intensive production on relatively small cultivated areas. No significant differences were observed between the groups in economic performance, although the farm net cash flow is considerably higher on the market-oriented farms.

Enterprise level analysis

Figure 4.4.2 shows major N flows and balances for the most frequently occurring enterprises. As a result of high inputs in the cash crops coffee and tea in terms of chemical fertilizers and FYM (coffee only), the partial balances for both crops were highly positive (tea: 36 kg N, 38 kg P and 14 kg K ha⁻¹ year⁻¹; coffee: 15 g N, 10 kg P and -20 kg K ha⁻¹ year⁻¹). The full N balance for tea and coffee, however, was negative as a result of high leaching and gaseous losses. The subsistence crops maize and maize/beans received only limited amounts of chemical fertilizer, and OUT 1 (harvested products that leave the farm) was very low too. Very little FYM was used for maize and maize/beans fields. Maize and maize/beans were grown at subsistence level; most of the harvest was used for home consumption (Fl 6) and hardly any

Table 4.4.1. Farm management, nutrient balances, and economic performance according to market orientation of farms expressed in % of gross returns sold.

	Market orientation		
	< 33%	33–66%	> 66%
N-balance (kg ha ⁻¹ year ⁻¹)	-26 ^a	-89	-106 ^b
P-balance (kg ha ⁻¹ year ⁻¹)	-2	5	6
K-balance (kg ha ⁻¹ year ⁻¹)	32 ^b	-12 ^b	-68 ^a
Partial N-balance (kg ha ⁻¹ year ⁻¹)	46	25	33
Net farm income (US\$ farm ⁻¹)	1380	1620	1455
Returns to family labour (US\$ day ⁻¹)	2.0	1.9	3.0
Farm net cash flow (US\$ farm ⁻¹)	180 ^a	765	1235 ^b
Cultivated area (ha)	6.7	4.3	1.7
Tropical livestock units	4.4 ^b	4.2 ^b	1.5 ^a
Zero grazing unit (1 = yes/2 = no)	2.0 ^a	1.5 ^b	1.4 ^b
Share livestock in total gross margin (%)	61 ^a	63 ^a	16 ^b
N-inflow fertilizers (IN 1 in kg ha ⁻¹ year ⁻¹)	9 ^a	18 ^a	45 ^b
N-inflow organics (IN 2 in kg ha ⁻¹ year ⁻¹)	54	21	14
N-outflow products (OUT 1 in kg ha ⁻¹ year ⁻¹)	17	13	25
Application on-farm produced manure (kg ha ⁻¹ year ⁻¹)	6000	4500	9000
Labour-intensive crops (days ha ⁻¹)	179	226	373
Labour-intensive livestock (days ha ⁻¹)	71	48	91

^{a,b} The mean difference is significant at $P \leq 0.05$ level.

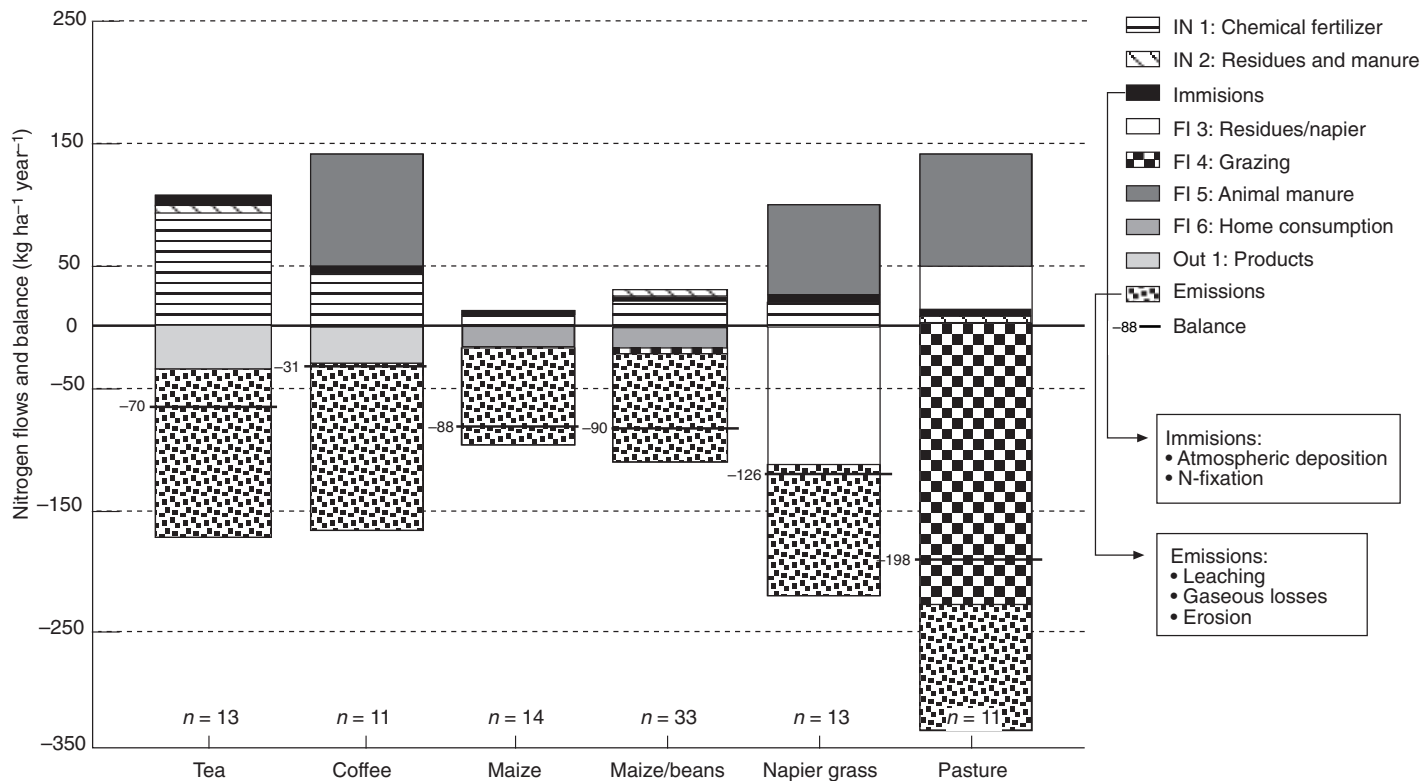


Fig. 4.4.2. Nitrogen flows and balances for tea, coffee, maize, maize/beans, napier grass and pastures. Figures are means for fields on 26 farms with a minimum surface of 0.1 ha and with a recorded harvest during the monitoring period; n = number of fields considered.

products left the farms. Despite low outputs, the balances for maize and bean fields were more negative than those for coffee and tea, since very few inputs were used for these crops.

The returns, gross margins and variable costs of coffee and tea were considerably higher than those of the major food crops (maize and maize/beans, Table 4.4.2). In cash crops, fertilization (manure in coffee and fertilizers in tea) is the major cost component, while for food crops, fertilizer and seeds are equally important cost components. Harvesting of tea led to relatively high costs of hired labour compared with the other activities.

On coffee, tea and napier grass considerably higher levels of fertilizers were applied than on food crops. Economic studies of the Fertilizer Use Recommendation Project (FURP, 1987) show that application of fertilizers to food crops is not economical in the short term, and the data show this is consistent with actual farm practices. However, low fertilizer use in food crops results in high replacement cost levels. The cash crops coffee and tea needed expenditures to replace the mined nutrients amounting to 20–30% of the gross returns, while for napier grass and food crops this is at least 70–80% of the returns.

Analysis of the zero grazing-napier system

In order to gain insight into the effectiveness of the zero grazing–napier grass systems, an analysis was made of the nutrient flows related to zero grazing animals, dunghills and napier grass plots. Figure 4.4.3 illustrates the flows taken into consideration. Zero grazing animals were fed concentrates from outside the farm (IN 2) and napier grass (FI 3) from within the farm, while the

Table 4.4.2. Economic characteristics and nutrient balances of major crops.

	Crops				
	Coffee (<i>n</i> = 9)	Tea (<i>n</i> = 11)	Napier grass (<i>n</i> = 11)	Maize (<i>n</i> = 11)	Maize-beans (<i>n</i> = 30)
Yield (kg ha ⁻¹)	2,900	3,300	35,000	1,800	1,100 [†]
Returns (US\$ ha ⁻¹)	1,355 ^a	620 ^b	645 ^b	85 ^b	205 ^b
Gross margin (US\$ ha ⁻¹)	1,115 ^a	470	435	50 ^b	170 ^b
Variable costs (US\$ ha ⁻¹)*	240 ^a	150	210 ^a	35 ^{bc}	35 ^{bc}
Fertilizers (US\$ ha ⁻¹)	50	135 ^a	60	20 ^b	15 ^b
Manure (US\$ ha ⁻¹)	180 ^a	10 ^b	140 ^a	1 ^b	4 ^b
Hired labour (US\$ ha ⁻¹)	60	130 ^a	55	25	30 ^b
N-balance (kg ha ⁻¹)	-36 ^a	-46	-154 ^b	-68	-74
P-balance (kg ha ⁻¹)	6	17 ^a	-10 ^b	-1	-2 ^b
K-balance (kg ha ⁻¹)	-4 ^a	-26 ^a	-153 ^b	-44	-37 ^a

^{a,b,c} The mean difference is significant at *P* = 0.05 level.

*Excluding costs of hired labour.

[†]Maize and beans yield added.

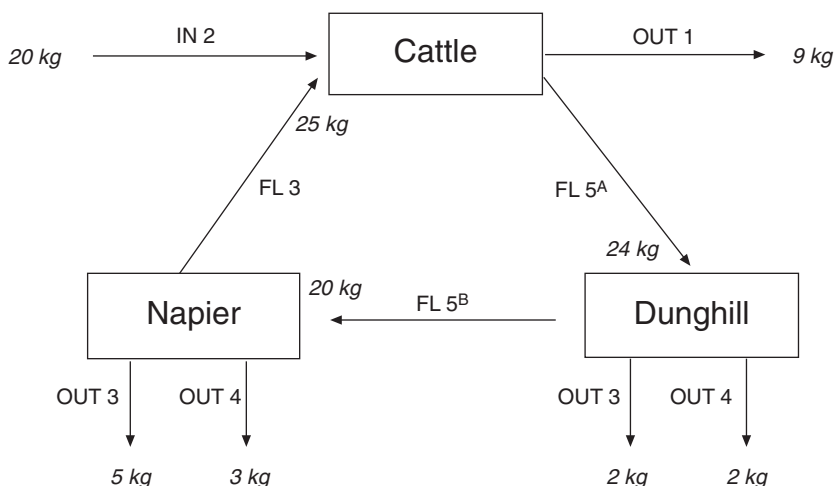


Fig. 4.4.3. Quantitative representation of the nitrogen flows (kg head⁻¹ year⁻¹) between lactating zero grazing cattle, dunghill and napier grass field. The figures are means for six zero grazing–napier systems from farms in Kisii (1), Kakamega (1) and Embu (4) and are standardized to a system with 1 full grown zero grazing animal and 0.3 ha of napier grass. The average zero grazing system consists of 1.7 full grown animals and 0.5 ha of napier grass.

animal products left the farm (OUT 1) and manure was excreted while the animals were corralled (Fl 5a), of which part was applied by the farmer to napier grass fields within the farm (Fl 5b). Before application however, losses occurred during storage and transport (OUT 3 and 4). Once applied to the field, further losses occur again through leaching (OUT 3) to deeper soil layers, and gaseous losses (OUT 4). Finally, napier grass was fed to the zero grazing animals (Fl 3). Hardly any chemical fertilizer was used for napier grass, whereas high outflows of N and K through harvested napier grass (Fl 3) were recorded. Total losses from this system were estimated at 12 kg N ha⁻¹ year⁻¹, which is 50% of the animal manure that enters the cycle. On average, 25 kg N ha⁻¹ year⁻¹ left the napier grass fields with the fodder, of which only 12 kg N ha⁻¹ year⁻¹ were effectively balanced through manure input. This means that napier fields were heavily mined. Because of low external inputs and high yields, napier grass realizes high gross margins, but from the nutrient balance it is clear that this high gross margin is achieved at the expensive of soil fertility depletion.

Applicability of *NUTMON* to Peri-urban Agriculture

The *NUTMON* methodology, with nutrient balance studies at the farm level, participatory development of INM technologies at the farm/village level, in combination with development of policy instruments at district or national

levels, can be a valuable tool in peri-urban agriculture research. Although the farm diagnosis tool, *NUTShell*, is flexible and can be applied to a wide range of farming systems, adaptations may be required to cope with features encountered in the farms but not yet incorporated in the concepts. To date, the *NUTMON* methodology has largely been applied to farming systems where soil fertility is a short-term constraining factor, or where there are concerns about longer-term soil mining. On the other hand, as discussed in the introduction, peri-urban agricultural systems, with their greater intensity of resource use, may face somewhat different soil fertility concerns, requiring some adaptations to the *NUTMON* framework. These include efficient use of inputs for both economic and environmental reasons, risks of using irrigation water or organic material contaminated with pathogens or heavy metals (see for example Niang, 1999). *NUTMON*'s applicability is in its value as an interdisciplinary approach or methodology for evaluating key issues relating to inflows and outflows (biophysical and economic) at a farm level that are then addressed through a participatory technology development process as well as a process of engaging key policy stakeholders.

For peri-urban systems, the specific inflows and outflows examined in *NUTMON* could be reduced in number to cover the easy-to-quantify inflows and outflows: N, P and K added through mineral and organic fertilizers, removed through crops (as products or consumed/removed residues). This seems more appropriate given that decline in nutrient availability is not as critical an issue. This would also place the emphasis on flows that the farmer manipulates directly, to support the development of efficient management strategies. This could also build on results from previous *NUTMON* projects that indicated that the detailed monitoring and inclusion of all flows seems excessive for initiatives with a participatory technology development component. Concentrating on the easy-to-quantify flows would allow a quicker diagnostic phase and more self-monitoring, as recommended by previous *NUTMON* experience (Van den Bosch *et al.*, 1998b).

The *NUTShell* model includes the homestead as a separate production unit. For urban and peri-urban systems, it may make more sense to concentrate initially on plot levels, particularly for intensive vegetable production. There seem to be fewer interactions with other farm-owned nutrient sources among such cropping systems, as compared to staple cereal crop systems. The intensive and commercial nature of the farming practice implies a greater use of purchased, as opposed to own, nutrient sources.

It would also be interesting and useful to add inflows and outflows of heavy metals. This would probably require the incorporation of water inflows, to capture their heavy metal components. The difficulty presented by heavy metals will be the lack of uniformity of concentrations in organic material or in water. Including water management is, as mentioned above, probably desirable in some sense as the use of irrigation is another key feature of the intensification process (particularly in semi-arid regions). Although it will be important to include aspects such as timing of water deliveries, in addition to simply total quantities, if the information and analysis are to be of interest to the farmer.

In summary, *NUTMON* could be adapted as an approach to soil fertility management in the peri-urban context in African farming systems by both simplification and extension. The simplification relates to focusing on the easy-to-quantify flows of major nutrient inflows and outflows. The diagnostic procedure could also be streamlined and with these changes more self-monitoring by the farmers could take place. The extension consists of incorporating other issues that are at least as important as nutrient availability when considering soil fertility or quality in these systems. These issues include water management and the deposition and build up of heavy metals. As an input–output framework, it is relatively straightforward to adapt the *NUTMON* methodology for additional flows. But the challenge, in so doing, will be to ensure that excessive complexity is avoided.

NUTMON's third phase of participatory technology development obviously demands an action on which the process can concentrate. In earlier *NUTMON* projects, this has typically been the development of nutrient management approaches emphasizing the integration of organic (typically manure and crop residues) and inorganic nutrient sources. For peri-urban agriculture, this possibility also exists but the organic nutrients of most interest are the various forms of solid and liquid urban organic waste (from both households and industry). These are already employed to some degree in peri-urban agriculture across the continent. But rapid urban growth has opened the possibility for newer and greater concentrations of organic waste materials becoming available. The techniques for processing and using this waste in agricultural production provide many opportunities for research and action. *NUTMON* is currently being adapted and applied in a project exploring, together with waste processors and farmers, the potential to re-use urban organic waste in Bamako and Ouagadougou. Partners for this EU-DG12 INCO-funded project, which began in 1999, include the Agricultural Economics Research Institute (LEI, The Netherlands), Alterra Green World Research (The Netherlands), the State Institute for Quality Control of Agricultural and Food Products (RIKILT-DLO, The Netherlands), Waste Consultants (The Netherlands), the Centro de Edafologia y Biología Aplicada del Segura (Spain), International Institute for Environment and Development (IIED, UK), Institut de l'Environnement et de Recherches Agricoles (INERA, Burkina Faso), Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût (CREPA, Burkina Faso), Institut d'Economie Rurale (IER, Mali), Cabinet d'Etudes Keita Kala Saba (Mali).

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4.5 Definition and Boundaries of the Peri-urban Interface: Patterns in the Patchwork

M. Adam

Natural Resources Institute (NRI), Chatham Maritime, Kent, UK

It is useful to have an idea about the nature, size, and demarcation of the 'peri-urban area', not only for the modelling of nutrient flows, but also to pave the way for adequate policy support. Three approaches to the demarcation of the peri-urban interface (PUI) as used by the research team for the Kumasi Natural Resources Management Research Project are presented in this chapter, together with some reflections on the nature of the problems faced by the inhabitants of these areas. A comparison with the findings of other research in the PUI is drawn and a definition proposed.

Key words: West Africa, Ghana, urban agriculture, cluster analysis, socio-economics, farming systems

Introduction

One of the divisions of renewable natural resource research within the portfolio of the Department for International Development (DFID), the sponsors of the work on which this chapter is based, is the PUI. But definitions of the PUI have been described as 'thin and inconsistent' and this leads to the suggestion that local factors are more important than generalized assumptions in characterizing the nature of peri-urban natural resource issues (Universities of Nottingham and Liverpool, 1999). The standpoint of this chapter is to take the local factors most evident in the PUI of the Ghanaian city of Kumasi and to consider the relevance of these factors to have common application and consequences in other cities' PUIs.

It should also be pointed out that, generally it is recognized that the peri-urban interface is not a discrete area but rather a diffuse territory identified by combinations of features and phenomena, generated largely by activities within the urban zone proper (Universities of Nottingham and Liverpool, 1999). Any attempts to define the boundaries of the area are, therefore, to

some extent doomed to inaccuracy and dispute and their value must be regarded as indicative of locations where it is likely that certain development issues predominate, rather than definitive of the limits of distinct regions of common features.

Why should we be concerned about defining the PUI besides for modelling purposes¹? Some authors question the very need for a concept of peri-urbanity in development parlance: for example, Sumberg (1996), in considering urban livestock production in Tanzania, concludes that there is little justification for policies specifically to support urban or peri-urban agriculture and that a food systems (economic/agro-ecological) rather than a demographic systems (urban/peri-urban/rural) approach is a more useful perspective in framing plans for 'sustainable cities'. For example, if the city lies in a tropical semi-arid zone with limited water supplies, the economic value of peri-urban dairying may be highly questionable, while it might be an excellent choice for a well-watered temperate zone. Agro-ecological and economic factors obviously have to be considered, but this chapter supports the idea that there are sufficient distinctive features of the PUI to warrant special consideration for development programmes.

The reason for definitions in the development context must be to develop policies and programmes geared to the specific needs of the people in a defined situation. The intensity and severity of the development issues and problems in the PUI could in theory either be an additive or reductive combination of those in urban and rural areas – Fig. 4.5.1 may help to illustrate these two positions. The opinions of those inhabitants of the villages near Kumasi canvassed in our participatory rural appraisal (PRA) and questionnaire surveys (the people in the situation) incline to the additive ('worst of both worlds') view.

What are these problems or threats? Some of them, and the opportunities available in the PUI, will become apparent in the discussions of the approaches to the definitions in the next sections. As far as farming is concerned, it has been suggested by Rakodi (1999) that in the early stages of urban influence the opportunities for farm enterprises outweigh the threats (but the beneficiaries tend to be larger farmers). However, in the later stages of urban influence, the threats to farm enterprises outweigh the opportunities and again it is those with the advantage of being able to sell land to developers who benefit.

Approaches to Defining the PUI of Kumasi

Three approaches to the discussion of the nature of the PUI are employed in the following sections:

- First, agricultural production is considered and the differences between urban, peri-urban and rural farming systems and changes occurring therein.

¹In the model used by Leitzinger for example (Chapter 4.2 this volume) the potential of replenishing soil nutrients depleted by: (i) urban and (ii) peri-urban agriculture is discussed. This requires the demarcation of the peri-urban production (nutrient mining) area.

- Second, market and transportation systems and their spheres of influence are considered.
- Third, cluster analysis is applied to a spread of mainly socio-economic variables taken from an extensive village survey.

The chapter concludes with a summary of the findings of these three approaches, considers which features are common or relevant to another peri-urban area in which DFID-sponsored research is taking place, and proposes a rephrasing of the DFID PUI definition.

Peri-urban agricultural systems

The terms urban and peri-urban are sometimes used interchangeably by authors when considering the agriculture of a region. For example, Yeung (1987) defines urban agriculture as food production within the urban *and* peri-urban area. Indeed, there has been a recent tendency to combine urban

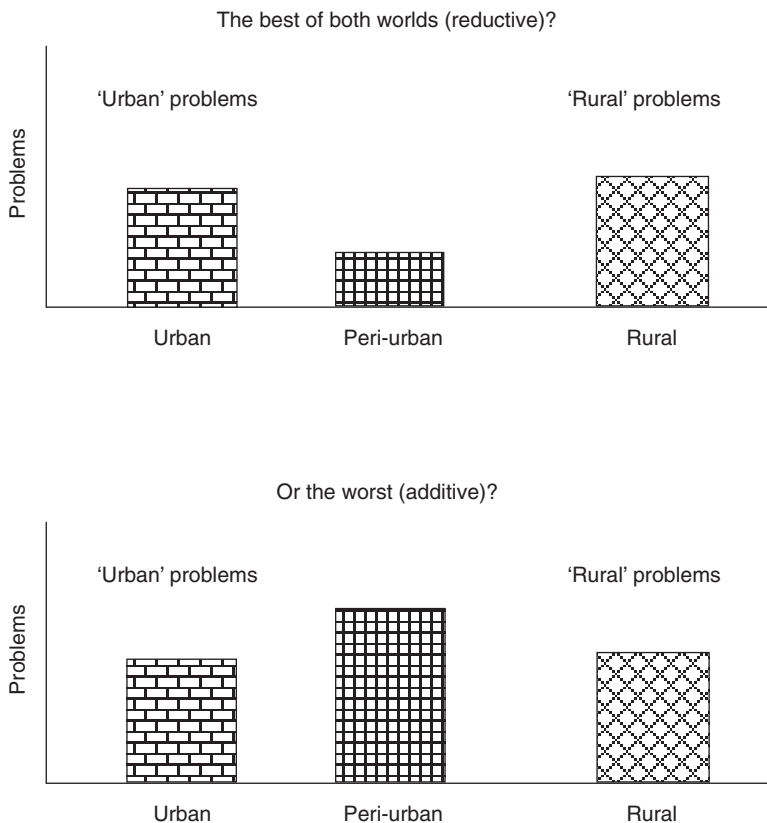


Fig. 4.5.1. Possible peri-urban problem situations.

and peri-urban agriculture as a single research and development area, known as UPA, 'urban and peri-urban agriculture'. The common features of the UPA system are its adaptability and mobility compared with rural agriculture and the competition for resources (land, water, energy, labour) that could also satisfy other requirements of the urban population (FAO, 1999).

Our starting point with the first and third approaches presented here was to take an arbitrary circle, with a radius of 40 km from Kumasi city centre, and examine agricultural and socio-economic conditions in selected villages within this radius. For the principal source of data for this chapter, the Village Characterization Survey (VCS), a stratified random sampling scheme was used. Stratification on the basis of access to the city was made by distinguishing three zones:

1. On road (no more than 2 km from a main road).
2. Off road (more than 2 km from main roads as shown on a 1:50,000 map).
3. Within 5 km of the city centre main market.

Sixty-six villages were selected on this basis, representing an approximately 9% sample of all villages within the radius described. A questionnaire was administered by teams of enumerators to groups of key informants within these selected villages. Data are also incorporated from a PRA by a multidisciplinary team of researchers carried out in six villages within this 40-km radius.

The results reveal differences in the farming systems changes as perceived by farmers from villages with different ease of access to Kumasi. Figure 4.5.2 illustrates this.

1. *Declines* in soil fertility and fallow periods are least remarked upon by those in villages with the easiest access to the city, although it has been pointed out that the *length* of the fallow period is least nearest the city centre. The average fallow period as reported by all villages declined from 6.2 years in 1983 to 2.8 years in 1997, and is shortest (zero) in many of the villages closest to the city. It seems probable that the perception in the villages closest to the city is that there has been some stabilization at a lower level of fertility; the decline in fertility having occurred there in earlier years.

2. In the least accessible villages herbicide use increase is most pronounced. Thus, this intensified farming system may well be a feature of these more distant villages.

3. This contrasts with the most accessible villages, which tend to report overall increases in maize and backyard farming (which was not noted at all in the least accessible villages). This could be due to the lack of land tenure security; maize being the shortest-term popular food crop (most suited to opportunistic cropping on undeveloped house sites), and the market for fresh green maize nearest the city.

4. However, the decline in cocoa cultivation and its replacement with maize–cassava systems is common throughout the area and varies little with accessibility.

5. In the villages with intermediate access both vegetable and commercial

poultry farming are recorded as showing greater increases than in villages in the other categories. Commercial poultry farming is recorded as having increased only in this category, while the increased use of poultry manure was noted in all villages.

6. High input costs were not given as a major change, and were more often reported in villages with better access to the city. This may be due to there being fewer cooperatives, which sell inputs at lower prices to farmers in the settlements nearest the city.

7. 'Modern methods' of farming were noted as being introduced in all villages approximately equally. Informants sometimes specified such practices as line planting, sole cropping, and the use of fertilizers and plant protection chemicals as 'modern methods'.

A picture of a spectrum of farming systems in transition may be derived from this information and the differences between the farming changes as related to accessibility taken as indicators of 'peri-urbanness'. To these indicators we can add those from the PRA, previously reported at an earlier IBSRAM meeting (Sarfo-Mensah and Adam, 1998), in which it was shown that a more-or-less radial pattern of distribution of spatially zoned farming systems could be distinguished. However, the most frequently occurring system, that of the bush fallow food crop farm, was found throughout the area.

Combining these two sources of information, we can suggest that a village with an intermediate degree of access to the city, postulated as 'peri-urban', would be expected typically to exhibit the farming systems features listed in Box 4.5.1.

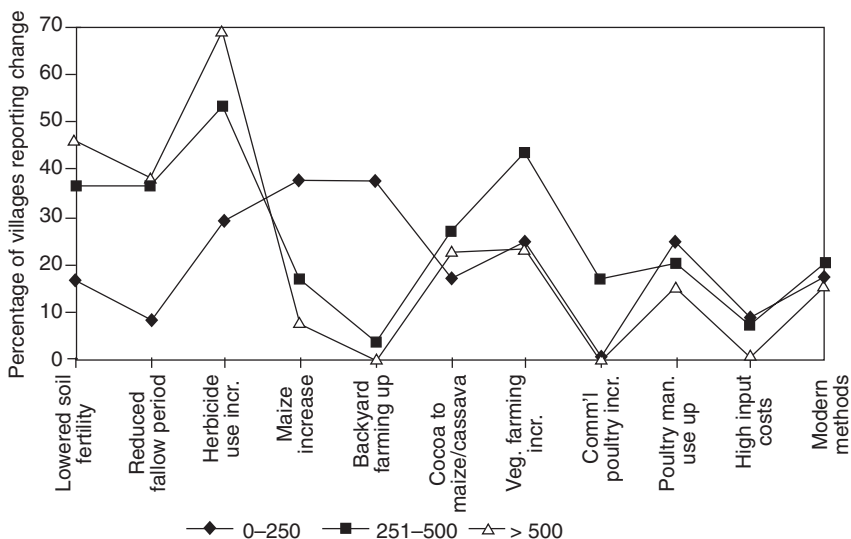


Fig. 4.5.2. Agricultural change and accessibility according to the Village Characterization Survey. Profile of reported agricultural changes since 1983 related to accessibility. Accessibility as measured by cost of *tro-tro* (minibus) to Kumasi in cedis.

Box 4.5.1. Features of peri-urban farming around Kumasi.

- Presence of commercial poultry farms.
- Presence of vegetable farming.
- Some tree crops, more than in the villages closer to the city but fewer than in those further away.
- Some intensified cereal crops, more than in the villages closer to the city but fewer than in those further away.
- Some backyard gardens, fewer than in the villages closer to the city but more than in those further away.

In more detail, the true peri-urban interface or 'rurban fringe' (Van den Berg, 1984) is shown to be that where competition for land use is at its most intense and change of land use, from agriculture to urban, is most rapid. The commercial poultry farming in this zone may be large scale in terms of capital invested and there is increasing demand for use of poultry manure in vegetable production systems. Traditional tree crops such as cocoa and oil palm are declining in areas to remnants of their former extent and intensive vegetable production is an increasing activity. Those farming the land are commonly tenants, immigrants to the village, of small plots less than 0.5 ha in the vegetable production system and there is a predominance of somewhat larger family holdings in the traditional mixed-cropping bush fallow system, which is breaking down due to the decline in the fallow period. The migrant tenants correspond to the 'rural vacators' and the family farmers to 'rural stayers' in van den Berg's classification. The geographical extent of this has its furthest points from the city centre at approximately 30 km.

The above characterization is an elaboration rather than any contradiction to the situation described by Wills (1962) for a 15-mile radius of Kumasi, which was 'intensive land rotation with negligible forest area remaining; the area of most commercialized food cropping'. Beyond that radius, in his description, lay the area of most extensive established cocoa, which has since declined generally in importance in the Ashanti Region due to the combination of crop disease, unfavourable economic returns and, according to the farmers, reduced and changed rainfall patterns.

Markets and communications (urban footprint study)

It has been suggested that peri-urban agriculture is 'farming and related activities that are significantly influenced by urban areas or municipalities' and that such influence is expressed normally through market forces (Aldington, 1997). To investigate the effects of these forces a brief study was commissioned from the Institute for Land Management and Development, Kwame Nkrumah University of Science and Technology – written up in the

project inception report (Blake *et al.*, 1997) – to help identify the Greater Kumasi city region using various simple indicators. Instead of first selecting an arbitrary geographical radius of the city and then examining the characteristics to be found therein, this approach aims to place approximate geographical boundaries on the spheres of influence of the city as defined by communication and marketing factors. To some extent this draws on the thinking of Rees (1992), in his analysis of the influence of cities, which defines the ‘ecological footprint’ of a city as the total area of land required to sustain a city.

Transportation

The most popularly used form of transport available to the general public around Kumasi is that of *tro-tros*. This is the Ghanaian term for a minibus, usually designed to carry 18 passengers, which plies a regular route, in this case around Kumasi. Twelve *tro-tro* routes radiate out from the Kejetia Lorry Park Terminus. Regular routes are followed, so villages on these routes have become much more accessible to the city. In addition, within a 10-km radius of the city centre, taxis also operate, but these tend to be more expensive – perhaps charging double the fares of *tro-tros*.

Tro-tros in Kumasi are regulated by the Kumasi Tro-tro Owners association, the Ghana Private Road Transport Union of the TUC (GPRTU), and this acts as the umbrella organization for the *tro-tro* routes. The organization is very powerful and unregistered *tro-tros* are not permitted to enter the *tro-tro* station. The station overseers representing these organizations were interviewed to determine the destinations of *tro-tros* leaving the Kejetia Lorry Park. As these overseers determine the ordered sequencing of vehicles on each route, they were able to provide information on the average number of vehicles and journeys per day. Travel patterns remained constant during the week, although at weekends the outflow to funerals tends to exceed the inflows to Kumasi. Station overseers and waiting drivers, plus a random sample of passengers, were interviewed about the average number of vehicles on each route per day, the average number of trips per day for each vehicle, the types of foodstuffs conveyed to and from Kumasi, and if the vehicle carried daily commuters to Kumasi. *Tro-tro* operators were interviewed to determine the number of vehicles per day travelling to outlying towns and villages.

Commuters were drawn from a radius of approximately 32 km, with extensions along major routes (source: interviews of *tro-tro* station overseers and a sample of passengers). A further detailed study of the spatial distribution of commuters into Kumasi would provide a meaningful indicator of pressures on natural resources in the peri-urban area and indicate those villages facing in-migration and from where (urban to peri-urban, as well as rural to peri-urban) and indicate consequent pressures on natural resources from these commuting pressures and the concomitant changed land and livelihood situations.

An outer zone was plotted on 1:250,000 maps showing the area in which at least five *tro-tros* each made at least five trips per day. It had been established that at the outer limits, loading, unloading, waiting and journey times meant that each vehicle was kept fully occupied for the working day between 5.30–6.00 a.m. and 6.00–7.00 p.m. The smaller journey-to-work or commuting zone, averaging about 32 km from Kejetia, with between 10 and 12 18-seater *tro-tros* carrying commuters per day, has also been drawn on the maps.

Markets

Information was also obtained from market queens² or traders in the villages visited by the Kumasi daily traders. Ten of these people, covering the main commodities, were interviewed in the main central market at Kejetia, and a similar number were visited in Asafo, a newer city-centre market. These key informants were also asked about the areas supplying perishable foodstuffs to the Kumasi markets, and the villages that depend on Kumasi for daily needs of meat, fish, perishable farm produce, imported items and health services. Traders themselves were interviewed in three other markets, which act as transfer stations for produce from the outlying villages.

The study found that the marketing system was complex but the marketing processes could be generalized to identify broad zones or spatial patterns. Each market queen takes responsibility for organizing the supplies of a particular foodstuff for the markets in Kumasi and for fixing prices³. Even when farmers or traders from the villages bring their foodstuffs to Kumasi, the market queens act as wholesalers and intermediaries between them and the small-scale retailers at the markets. Within a distance of about 16 km, villagers tend to transport their farm produce to Kumasi themselves, combining this marketing journey with shopping for themselves in the city: beyond this distance the villagers tend to wait for the traders or wholesalers to visit them. In either case their retailing activities in the market will be controlled by the market queens. The advantages of proximity to the market, with lower transport costs and easier access to the urban market, thus tends to be counteracted by the mechanism of the actual process of marketing manifested by the control exercised by the market queens.

On the basis of their information, a zone around Kumasi was identified that had daily interactions with Kumasi. This included:

1. Villages visited by Kumasi traders on a daily basis. These might be individual traders or wholesalers, using either their own or hired vehicles, or making use of public transport, although occasionally traders might combine together to send a truck to collect produce.
2. Villages dependent on Kumasi for their daily needs of meat, fish, perishable farm produce and imported items. Very few villagers have refrigerators or

²A market queen is a woman who acts as the leader of a group of market traders, usually in a limited range of commodities, and who has some power in controlling the prices of commodities on a day-to-day basis.

³See Clark (1994) for information on market conduct in Kumasi Central market.

the money for bulk purchases and so rely on Kumasi. Traders from outlying villages travel to Kumasi, often with locally-produced goods, on an early *tro-tro* at 5.30–6.00 a.m., spend about an hour or so obtaining produce or goods in Kumasi, before returning with perishable commodities to sell at their outlying village markets around 9.00 a.m.

3. Areas supplying perishable foodstuffs to the Kumasi market. Within this area no zones of geographical specialization on particular crops could be identified.

Kumasi is in addition the focal point of transportation routes to all parts of the country so its commodity flows are complex. The whole country, perhaps even the entire coastal West Africa, could be defined as the area of supply for its foodstuffs. The peri-urban areas are not the sole suppliers of foodstuffs for the city. Areas beyond its daily sphere-of-influence may be able to supply produce at lower unit costs, or may have more land available, or have other comparative advantages such as climate, soils, fewer pests, cheaper labour, etc., and be able to overcome higher transport costs to compete with the city region. This is particularly true for less perishable staples – e.g. maize (Techiman), yams (Ejura, Kintampo), cassava (Greater Accra), millet and legumes (Northern, Upper East and Upper West Regions), but also more perishable crops like avocado and tomatoes (irrigation schemes in Upper East Region). Some heavy, bulkier crops like cocoyams and plantains still tend to be supplied from within the peri-urban region.

In terms of the market information thus gleaned, the outer zone as defined by the *tro-tro* survey is a composite of all three market zones described above as 1. to 3.: those villages visited by Kumasi market traders on a daily basis, together with the villages dependent on Kumasi for their daily needs of meat, fish, perishable farm produce and imported items. This, together with the inner, commuting zone, which constitute two definitions of Kumasi's urban footprint, have been entered on the geographical information system, KUMINFO, which has been developed to facilitate this research. Figure 4.5.3 shows the Kumasi urban footprint boundaries thus derived, with the outer zone referred to as the City Region definition.

Leeming and Soussan (1979) have noted that it is important to distinguish between 'urban fringe' and 'hinterland', concepts that relate to peri-urban systems, but are often confused together. In the urban fringe, the city is expanding physically into former rural areas, bringing about a change in land use and livelihoods. This is a zone of direct impact of the city and where effects such as pollution from the city are likely to be felt. In the hinterland, people use the city in terms of trade, services, and administrative functions. Expansion of buildings and pollution effects do not necessarily impact directly on those living in the hinterland, which is a wider, generally market-related, zone of influence. There are no clear boundaries between the two zones, but they do relate to different concepts of peri-urbanity. It is not improbable that in our study the outer, daily marketing zone is an area with the characteristics of the 'hinterland' while the inner, commuting zone has the characteristics of the 'urban fringe'.

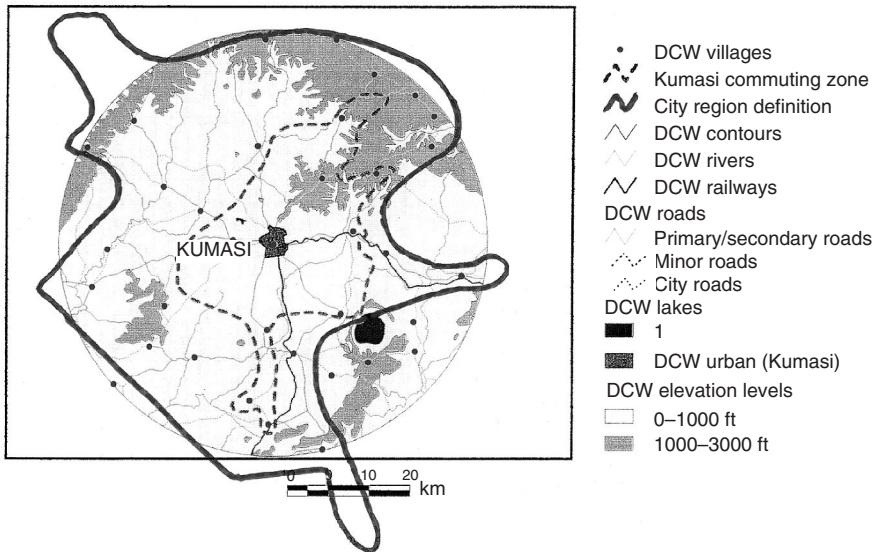


Fig. 4.5.3. Kumasi's urban footprint. DCW, digital chart of the world.

Cluster analysis: variation in socio-economic characteristics between villages

Sixty-five variables that were felt most useful for differentiating between urban, peri-urban and rural villages and which were recorded in the VCS were selected for a cluster analysis in order to try to identify groupings of the villages so that villages within the same cluster were relatively homogeneous, while villages that were not in the same cluster were considerably different. The aim was to identify clusters that could be usefully characterized as 'urban', 'peri-urban' and 'rural', and then to investigate the differences among the clusters for key characteristics in order to say something about the features of the three zones. This analysis was done in the statistical package GENSTAT.

The 65 variables include the proportions of the land-use types in the village area, the presence or absence of facilities such as schools and clinics, marketing patterns, employment, cost of *tro-tro* to the city, length of fallow periods, cropping patterns, number and severity of land disputes and degree of social problems such as teenage pregnancy; all as reported by the groups of informants met in the villages. Each variable was given equal weight in this analysis, and villages were grouped on the basis of their mean 'similarity', averaged over all of the variables.

The cluster analysis suggested that grouping villages into either six or three groups was sensible. Two groups – one 'rural', one 'urban' – were the same in both grouping methods; the three-group case came from merging four clusters that were clearly in-between the extremes of the two other clusters. In order to try to understand the transition from urban to peri-urban to rural, it was felt best to use the three-group result, with the central group representing 'peri-urbanity'. The number of villages in each of the three clusters was 11, 37 and 18 for the urban, peri-urban and rural clusters respectively.

Once the cluster analysis had suggested a sensible grouping of villages, the three clusters were compared for each of the variables used in forming the clusters. This highlighted for which variables there were marked differences between the clusters, and for which the differences were relatively small. For the majority of variables the central or 'peri-urban' group was characterized by values intermediate between the outer groups but for some variables this cluster of settlements is distinct in numerical terms or is at one or other extreme of the scale. These variables are shown in Box 4.5.2.

The villages in the different clusters have been demarcated on KUMINFO and the result is shown in Fig. 4.5.4.

There is a strong effect of proximity to the city on urban characteristics, but the definition becomes less clear when the peri-urban/rural distinction is considered. Neither a pattern of peri-urban settlements following the main roads nor one related to radial distance from Kejetia can be distinguished readily. One factor that may be giving rise to the results on this figure could be related to the size of settlement: most of the off-road 'peri-urban' villages are larger than the off-road 'rural' villages, and in particular those to the north-west are large settlements.

Summary: Characteristics of Peri-urban Systems

Looking at the results from these and other project analyses, certain general characteristics of the Kumasi peri-urban interface emerge. These are summarized in Box 4.5.3.

The first and most notable feature is that the peri-urban zone is not static in time or space. It is an area that is in transition – moving from rural to urban. Rural villages become engulfed by residential development over time, and the zone expands outwards from the city. The changes in land use reflect the underlying changes taking place in the economic and social structures of the inhabitants.

Box 4.5.2. Positive indicators of a peri-urban (as opposed to urban or rural) settlement in the Kumasi study area.

- Cost of *tro-tro* (minibus) to city centre is in the intermediate range.
- More than twice as likely to have ongoing land disputes than either urban or rural settlements.
- More likely to have a junior secondary school.
- More likely to have a health clinic (as opposed to a nearby hospital or no health facilities at all).
- Recent improvements in health, electricity and public toilet facilities.
- However, human waste management likely to be an important problem.
- Environmental degradation less recognized than elsewhere as negative change in recent years.
- More likely that farmers sell their tomatoes in Kumasi (as opposed to locally or elsewhere).

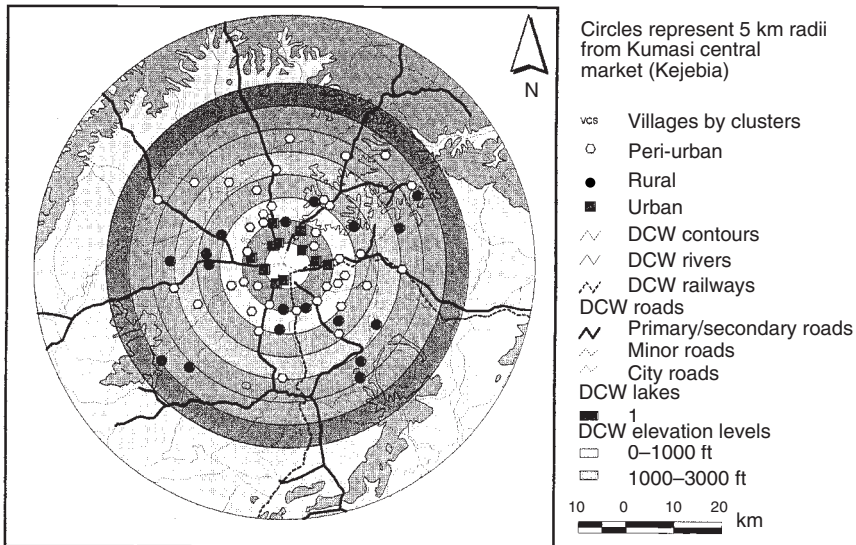


Fig. 4.5.4. Spatial representation of cluster analysis of Village Characteristic Survey (VCS) villages. DCW, digital chart of the world.

Box 4.5.3. Kumasi PUI characteristics.

- Dynamic in space and time.
- Areas within the zone are heterogeneous.
- Competition for land between agricultural and non-agricultural uses.
- Competition for jobs between agricultural and non-agricultural work.
- Changing social and economic balance between indigenous and immigrant inhabitants.
- Increasing dependence on the urban centre.
- Increased facilities that may speed up development.
- Increased pollution and waste disposal problems.

Within the zone, the rate of urbanization is variable: villages with a very rural aspect are surrounded by those that are very urbanized. Given the dynamic nature of the zone, it might be expected that some areas adapt and change faster than others.

Urban expansion increases demand for land. This has effects on the land markets and land tenure systems. Peri-urban areas are characterized by competition over land between agriculture and non-agricultural development. The outcome of this competition will depend on the structure and conduct of the land markets, and in differences in regulations and tenure between farmland and non-farmland.

There is also increased competition between agricultural and non-agricultural work. Peri-urban inhabitants have more opportunities to move into non-farm jobs in town than their rural counterparts, although they may be

constrained by lack of resources in doing so. Readily available supplies of labour do not necessarily translate into cheaper agricultural labour if urban-based jobs offer higher returns. The structure of the labour market, including barriers to entry such as training and capital requirements, are likely to affect movement into non-farm jobs.

Increasing populations leading to increased pressure on natural resources are occurring throughout Ghana. The distinguishing feature in peri-urban areas is the speed of population increase caused by in-migration. In addition to competition over local resources, in-migration to peri-urban areas means a changing social balance between indigenes and immigrants with resultant changes in community structures.

Rural villages in Ghana are rarely self-sufficient and have many forms of linkages with urban centres – through trade, migration and education. However, dependency on the urban centre is likely to increase significantly in peri-urban systems. First, through a greater proportion of inhabitants, both immigrant and indigenous, working in the city rather than the immediate, local area. Second, through the decrease in food self-sufficiency and growing reliance on the market.

An increase in facilities such as piped water, electricity, schools and health facilities may be characteristic of peri-urban areas. However, this will depend on the ability and willingness of local communities to organize installation of facilities. The influx of higher-income outsiders, unwilling to accept a poorer provision of infrastructure may also lead to pressures for these facilities and services to be provided, either by the resource-short public sector or through community or self-help efforts. Areas with such facilities build up more quickly, as people building houses prefer these areas to areas without facilities.

Pollution problems such as contaminated water and waste disposal problems are features both of proximity to the town, with its inadequate resources for dealing with waste products, and also of the transformation of rural into urban village in the peri-urban zone itself. Procedures that were adequate for dealing with waste in rural villages with plenty of land are no longer adequate to cope with the increased population in these peri-urban villages.

Conclusions

Applicability to peri-urban interfaces of other cities

The DFID research programme in the PUI selected Kumasi in Africa and Hubli-Dharwad in India as cities for study. The Hubli-Dharwad studies have also conceptualized the peri-urban interface as dynamic in terms of socio-economic, institutional, and environmental change, with intensive flows of commodities, labour, waste, pollution, and energy between urban and rural areas, and have concentrated on the description and analysis of these flows in defining and understanding the PUI. Some broad comparisons may be drawn between the two cities and are illustrated in Fig. 4.5.5.

<u>KUMASI</u> • Land tenure insecurity • Short-term crop farming systems predominate • Women especially under poverty threat • Waste management systems haphazard but improving • Information gaps for planning, and institutional hiatus		<u>HUBLI-DHARWAD</u> • Land tenure relatively secure • Some tree crop farming systems • Women especially under poverty threat • Waste management systems established but challenged • Planning information generally available, institutional hiatus
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Fig. 4.5.5. Comparison of some characteristics of the peri-urban interface (PUI) of the two cities selected for the DFID PUI research programme.

The similarities between the two situations are most pronounced in the area of institutional inadequacy to cope with the rapidly changing problems of the PUI and the threat to the livelihoods of women. Kumasi has a particular problem in the dysfunctionality of the land market caused by the overlap of the traditional chiefly powers of land allocation with the operation of a supposedly regulated modern land market. This affects the continued viability of agricultural production in the PUI and is related particularly to the uncompensated dispossession of farmers of their lands for urban expansion, women being more likely to depend upon their farms for livelihoods than men. This tendency has also been noted in Accra (Armar-Klemesu and Maxwell, 1998).

However, in the case of waste management the farmers of the Hubli-Dharwad PUI have a wealth of experience in the use of composts and municipal waste (Universities of Birmingham, Wales and Dharwad, 1998); there is an established cultural familiarity with the idea of using both forms of waste for soil amelioration, which is lacking in Kumasi. The Kumasi project in its final phase is working with farmers, extensionists and a non-governmental organization (the Ghana Organic Agriculture Network) to encourage the use of poultry manure and composts.

Definition of the PUI

The definition of the PUI originally suggested in DFID's Renewable Natural Resources Knowledge Strategy for its natural resource research programmes is: 'The peri-urban interface is characterized by strong urban influences, easy access to markets, services and other inputs, ready supplies of labour, but relative shortage of land and risks from pollution and urban growth.'

In general, the characteristics outlined in this chapter accord with the DFID definition. There is easy access to markets, services, and other inputs as

transport to Kumasi is good. The question is open as to whether peri-urban inhabitants have a greater advantage than those in rural areas (who may compensate in marketing, for example, by greater economies of scale) or can afford the services available. There are ready supplies of labour, but agricultural wages do not compete favourably with those for non-farm work and the labour force is drawn for preference to the non-farm work⁴. Shortages of land and urban growth are key factors and risks from pollution occur despite the relative lack of industrialization within Kumasi. Our Kumasi work would suggest therefore that a modification to the definition would have more validity for the situation there: 'The PUI is characterized by strong urban influences, including increased possibilities for marketing of farm produce, provision of inputs and services, and non-farm employment, but exacerbated competition for land, inequities in its distribution, and risks from pollution.'

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⁴One common feature of Kumasi and Hubli-Dharwad is that the ratio of non-farm to farm labour daily wages is similar (at about 1.6).

⁵Project coordinator Professor R.K. Kasanga of the Institute for Land Management and Development.

⁶Dr K. Williams of the Department of Geography.

⁷Project leader Professor B. Blake of the Natural Resources Management Department.

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Urban Agriculture: International Support and Capacity Building in Africa

C.J. Sawio¹, L. Spies² and D. Doucouré³

¹University of Dar es Salaam, Dar es Salaam, Tanzania;

²Technikon Pretoria, Pretoria, Republic of South Africa;

³African Institute of Urban Management (IAGU), Dakar, Senegal

The chapter gives an overview of international efforts and initiatives to strengthen urban and peri-urban agriculture with special reference to related networks in Africa.

Key words: Africa, urban agriculture, development aid, institution building, networking, IDRC

Introduction

Growing recognition of the importance and significance of urban agriculture (UA) has occurred worldwide (Dubbeling, 1998). This is becoming even more significant because globally, by 2020, food production could fail to keep pace with increases in food demand from the growing population in the developing countries, given current trends. UA has a long-established history in Asia and also in western countries. Now it is expanding rapidly in Africa and Latin America. It is documented that for the past 20 years or so, urban agriculture has been expanding globally. It is largely a response to the market demands arising from rapid urbanization (Smith and Olaloku, 1998). It is perhaps expanding more rapidly than urban populations and associated economies in many developing countries (Smit *et al.*, 1996). Urban and peri-urban agriculture is being seen increasingly as an important component of urban development, and urban environmental management. It can be a viable source of incomes, jobs, and food for the urban poor. For the sub-Saharan region,

dented by poverty, rapid population growth, civil strife, refugee crises, environmental degradation and unstable economic and political conditions, urban agriculture is an alternative source of employment, household incomes, nutrition and food security among many low-income urban dwellers.

The concept and definition of urban agriculture is fairly recent in mainstream research topics. It is gaining currency in research on urban systems, environmental planning and management, and sustainable development. UA is now recognized as a crucial component in cities' social, economic, environmental and ecological benefits, if carried out in an environmentally friendly manner. UA, broadly defined¹ as the production of food and non-food items through cultivation of plants, tree crops, aquaculture and animal husbandry within urban and peri-urban areas (Mougeot, 1994), is an omnipresent, crucial and potentially sustainable survival livelihood strategy for urban poor households.

Viewed much more broadly, urban and peri-urban agriculture focus on urban cultural values, natural, human and fiscal resource use, land-use planning and management, food and energy production, food security, technology, education, recreation, environmental conservation, micro-climate modification, income generation and recycling of wastes and used water. There is ample evidence today, that the spatial growth and socio-economic importance of urban and peri-urban agriculture in African cities are fairly well documented. Apart from crop production, livestock production is expanding around cities (Mosha, 1991; Sawio, 1993, 1998; Maxwell, 1994; Mlozi, 1995). Nearly 25–36% of surveyed households in a 5-km radius in Kampala, produce and market staple food such as cassava, maize and beans as well as poultry meat and eggs, pigs and other small livestock (Maxwell, 1994).

Global UA Trends

In the search for more meaningful development in balance with the environment, urban agriculture has been recognized by the world community as one viable urban development option. It has been noted that:

Officially sanctioned and promoted, urban agriculture could become an important component of urban development and make food available to the urban poor. The primary purpose of such promotion should be to improve the nutritional and health standards of the poor, help their family budgets (50–70% of which is usually spent on food), enable them to earn some additional income and provide employment. Urban agriculture can also provide fresher and cheaper produce, more green space, the clearing of garbage dumps, and recycling of household waste.

(WCED, 1987)

¹In other words, UA is an activity that produces, processes, and markets food and other products on land and water in urban and peri-urban areas, using intensive production methods and (re-)using natural resources and urban wastes (CFP, 1998).

Indeed, the Agenda 21 (Conference on Environment and Development, Rio de Janeiro, 1992) stresses the need for innovative and integrated strategies in urban land-use planning, including urban and peri-urban agriculture. Often this involves urban poor small-scale activities in food production and processing, marketing, and recycling and re-using of urban wastes.

Research and development in UA began in the late 1970s and early 1980s. Some of the key topics then included nutrition promotion, alleviation of hunger, scavenging, waste treatment and nutrient recycling, and dynamics of the informal sector. The International Development Research Center (IDRC) has always been a leader in this field. The United Nations University, through its Food-Energy-Nexus Programme in the 1980s also led the way in UA research. However, international development cooperation in UA began in the 1990s. Today, after a number of researches unearthed the contribution and role of UA in both advanced and developing countries, international agencies have become more aware of the importance of the sector. They have seen the need to pool resources together to support it and to enhance research capacity and disseminate pertinent technical information on the industry. An International Support Group on Urban Agriculture (SGUA) has been established. Pioneered by IDRC, a new Global Facility for Urban Agriculture (GFUA) was created in March 1996 at an international consultation by the SGUA. The SGUA was formed by the United Nations Development Programme (UNDP) in 1992 to examine issues on urban food security and urban agriculture especially in developing countries. The GFUA, as a multi-partner group aims at promoting the sustainable use of UA worldwide. Membership has grown substantially, including: IDRC, FAO, UNDP, Natural Resources Institute (NRI), International Food Policy Research Institute, World Bank, Consultants for Development (The Netherlands) (ETC), Economic Development Institute (World Bank), Directorate-General International Cooperation (DGIS, The Netherlands), Germany Agency for Technical Cooperation (GTZ) and others. In Europe, the European Support Group on Urban Agriculture has been established.

There is growing global interest in using UA to influence policy on urban development, urban planning and environmental management, food security improvement, building of healthy and safe urban systems, strengthening poverty alleviation and other policy formulation, and implementation for sustainable urban development.

Arguably, the international agencies have realized that there is a need to develop proactively the concept of UA and to demonstrate its potentials as a development tool. One among many objectives is to show how UA can be used as viable productive means to manage the urban environment on the one hand, and on the other hand how cities can use the concept and the practice of UA to increase their employment opportunities, incomes, food self-reliance, and healthier, greener, livable and sustainable urban landscapes.

While urban and peri-urban agriculture (UA and PUA) contribute to food security and income generation, 'improvements to the environmental and human health are important by-products. Increasingly, policy makers are taking

advantage of this potential UA benefit to strengthen environmental and urban planning policies. The production of trees, shrubs, flowers, and ornamental plants can beautify the city, cool its climate, and absorb air pollution and odours. But the most significant link between UA and environmental and public health is waste management' (CFP, 1998). Urban waste production is growing in all cities globally, and the potential for sustainable UA to serve as one of the tools to deal with this urban waste, both as an end-use and as a treatment technique, is promising (CFP, 1998).

With regard to numbers of people involved in UA worldwide, estimates presented by The Urban Agriculture Network (TUAN) a non-governmental organization (NGO), show that there are about 800 million people practising UA worldwide. Of these, 200 million are producing for the market, and 150 million practise UA full-time. Urban agriculture will continue to expand in the decades ahead. It is estimated that between 1993 and 2005, UA might increase its share of world food from 15% to 33%. Its share of vegetables, fruits, meat, fish and dairy products consumed in cities could rise from 33% to 50%, and the number of urban farmers producing for the market might increase from 200 million to 400 million (CFP, 1996).

Numerous statistics from urban and peri-urban agriculture literature in East and Southern Africa attest to the growing and expanding practice and importance of this sector. It is now accepted that both play important roles, particularly in:

- employment and income generation among the unemployed and low-income urban households;
- provision of supplementary income to middle class workers and poorly-paid urban dwellers;
- augmenting food security of urban households too poor to have the purchasing power to buy the food from the market;
- bridging the gap between food demand of rapidly growing cities, the poor, and inadequate rural food production and supply systems which is often rendered ineffective due to poor transport infrastructure;
- provision of commercial and economic investment alternatives for better-off urban dwellers who have interest in investing in intensive market gardening, meat and milk production in urban and peri-urban areas;
- provision of opportunities to recycle biodegradable solid wastes for composting for re-use as fertilizer and re-use of waste water for floriculture and urban forestry irrigation.

Regional Networks

While research on UA is increasing and there is a growing global interest in the potential of UA as a component in urban development, planning and management, a gap is rapidly developing between the demand of governments

and organizations for guidance on UA and the supply of UA professional expertise and institutional capacities. This is especially critical in the developing countries. In South Africa for example, UA is seen at the national level in the policy context of Agenda 21 and the Reconstruction and Development Program. There is a need to develop a national strategy for sustainable development by 2002. A new unit in South Africa is being established in the Office of the Deputy President for that purpose. As other countries within the region may be interested in UA, there is a need to establish an appropriate network.

Through IDRC's Cities Feeding People (CFP) Program Initiative (PI), capacity is being built to support development research to remove constraints and enhance the potential for UA interventions to improve household food security, income generation, public health, and waste and land management (CFP, 1998). The CFP-PI programme's specific objectives, which are the foundations for the establishment of UA Research and Development/Training Networks, are as follows:

- 1.** To strengthen local research capacity and generate information on UA at the household and community level so that cities can formulate and implement policy and technology options primarily for the benefit of the urban poor.
- 2.** To mobilize and enhance regional capacities to share experiences in UA, identify common policy and technology obstacles, and share and adapt solutions through training and networking.
- 3.** To influence governments, policy-makers, and international agencies to effectively incorporate UA in their development programmes.

In order to realize these objectives and to tackle critical UA problems, the CFP strategies focus, among others, on:

- Formalizing partnerships between individuals and organizations with UA knowledge.
- Ensuring that UA initiatives, including development research, must be promoted not as ends but as means. Policy and technology interventions in UA should be seen as components of larger development strategies aimed at urban food security, poverty, income generation, environmental improvement, and gender and ethnic dynamics.
- Ensuring that UA initiatives, including development research, must consult appropriate stakeholders when designing, monitoring and evaluating policy and technology interventions. These stakeholders include community-based organizations, NGOs, professional associations, municipal and national governments, research institutes and external support agencies.

In the frame of the CFP-PI, IDRC initiated the establishment of two networks on urban and peri-urban agriculture in Africa, one in East and Southern Africa and the other in West and Central Africa.

Constraints/problems of concern

The proposed networks aim at removing constraints and problems concerning the promotion and management of urban and peri-urban agriculture in the member countries. It has been realized, pursuant to the accumulated experience of IDRC project recipients and IDRC knowledge of the larger literature on UA, that the constraints and problems which constitute the limiting factors vary from region to region. In both West–Central and East and Southern Africa, the constraints include:

- lack of documentation on and attention to UA by municipal authorities, especially in West–Central Africa;
- lack of consideration of UA in sectoral planning processes, especially in West–Central Africa;
- lack of information on UA links with the rest of the economy for municipal policies in both West–Central and East and Southern Africa;
- producers' lack of market information and weakness of their organizations in both West–Central and East and Southern Africa;
- under-use by state and local development planning of knowledge and know-how generated by specialized research entities especially in West–Central Africa;
- lack of inter-connection among researcher entities and of collaboration between researchers, producers, the state and local communities, particularly in West–Central Africa;
- lack of training on UA for planners and of practical UA models for use in local interventions especially in East and Southern Africa;
- weak institutionalization of UA experiences on record in both West–Central and East and Southern Africa.

Other major constraints mentioned for West Africa are access to land, water quality, access to inputs, and commercialization.

In West Africa, the network was initiated in collaboration with the Conference des Responsables de Recherche Agronomique en Afrique de l'Ouest et du Centre, the Urban Management Program and the Municipal Development Program. It will cover in its first phase some of the French-speaking countries in West Africa (Mali, Senegal, Niger, Burkina Faso, Mauritania, Ivory Coast and Benin) and will extend later to Central Africa countries². The network is a regrouping of public and private institutions, researchers, national and sub-regional associations and organization, and individuals. The brief of the Institut Africain de Gestion Urbaine (IAGU) is to animate, to facilitate and to coordinate the network establishment at the regional level.

²Editors' note: The network does not cover anglophone West Africa. However, IDRC and other donors confirmed their commitment to the English-speaking countries in West Africa, also with regard to urban and peri-urban agriculture. IDRC, for example, approved a project submitted by IBSRAM on urban waste recycling for (peri-)urban agriculture in three Ghanaian cities.

The network is designed to favour the exchange of information, knowledge and experiences in fields of (peri-)urban agriculture. It is an area of dialogue, a framework of activity coordination and integration, and development of initiatives and experiences.

The network should promote evaluation, documentation and dissemination of experience together with farmer training and policy formulation that aim at the sustainable development of urban agriculture including inter-organization exchange, decision-makers sensitization, etc.

The network's principal objectives are:

- To support and coordinate network member activities.
- To undertake research work especially on: farmers' access to land and water, the use of waste water and solid waste as organic supply, economic impacts of urban agriculture, urban agriculture effects on food security, etc.
- To document and to disseminate various experiences developed in West-Central Africa (workshop, quarterly report, and publication on sub-regional initiatives and experiences and network activities, management of website and data bank).
- To train network members and actors on techniques, institutional and policy aspects and financing mechanisms linked to urban agriculture.
- To promote politics favourable to urban agriculture (lobbying).
- To develop research programmes and seek financing from international, regional, and national institutions.
- To favour growers' associations and network establishment in the different countries involved.
- To carry out studies and research missions in the field of UA for international, regional, and national organizations, public or private.

In East and Southern Africa, the anticipated network will be known as Urban Agriculture Network for East and Southern Africa (UANESA), with focus on development research and training. This is for large parts of the anglophone African countries, the founding members being Kenya, Uganda, Zimbabwe, Tanzania, and the Republic of South Africa.

In view of the constraints/problems of concern mentioned above, the initial proposal for the establishment of UANESA aimed at:

1. Developing a Pilot UA Training Curriculum. This will design courses, syllabuses, and teaching materials in the sub-region. The network pilot training curriculum is expected to be built upon regional documented materials and experience regarding UA and PUA research. Upon successful establishment of UANESA and production of the regional UA curriculum, the curriculum will be for undergraduates and graduates, urban and regional planners, municipal authorities and other professionals interested in the development of sustainable urban environmental systems. This training curriculum can be supported by the IDRC-launched *AGROPOLIS* Award Programme for graduate development research in UA.

UANESA will design means to carry out the actual teaching and/or training at the lead institutions in the network. The lead institutions are:

- The Department of Geography, University of Dar es Salaam.
- The Pretoria Teknikon, Pretoria, South Africa.
- The Makerere Institute for Social Research, Kampala, Uganda.
- The Environment and Development-Activities, Zimbabwe in Harare, Zimbabwe.
- The Mazingira Institute, Nairobi-Kenya.

These institutions will be responsible for carrying out the activities of UANESA and will include other institutions/organizations as considered feasible and appropriate. In the East and Southern African context, the initial UA formal training is slated to begin at the Teknikon, Pretoria.

2. Updating UA and PUA information through development research and sharing of research knowledge, especially through e-mail and Internet communication throughout the sub-region. The key areas of research, knowledge exchange and sharing as well as training will include:

- Appropriate and affordable locally developed technologies to support UA.
- Socio-economic impacts and interventions to develop and enhance urban food self-reliance and urban food security; income generation; improved urban nutrition and gender analysis in UA production systems; dissemination of producer and market information, and organization of UA production and marketing systems information in the sub-region.
- Documentation and strengthening of UA policies for urban environmental management planning in the network region.
- Collaborative efforts in forging better institutional links in tapping UA experiences on record and removing institutional constraints that militate against regional support for UA development. In effect it entails formulating UA policies and documenting how to implement them.

3. Developing city-specific UA practical models/demonstration urban farming projects to be used from time to time for training of urban farmers, urban planners and municipal decision-makers. Through these UA model farms and/or gardens, knowledge will be imparted to stakeholders interested in incorporating UA activities in urban ecosystems in East and Southern Africa. The practical UA models are expected to be able to provide service delivery and support to ongoing UA and PUA research in the region.

Moreover, UANESA will generate and disseminate new information from more research that will produce a better picture of *the-state-of-the-art and practice of UA*. It will enhance the contribution of UA and associated research in three identified areas:

- 1.** appropriate and affordable UA technologies that can be developed, adopted and transferred easily within the sub-region;
- 2.** small-scale urban poor farmers' production and marketing information to enhance food security and urban nutrition;

3. better UA sectoral policies and urban environmental planning policies that specifically address UA and environmental problems for healthier cities within the sub-region.

Network support and funding

Since the network is supposed to link into the global initiative on Urban Agriculture Research and Development, it is perceived that the supporting, funding and/or donor institutions will have to be international, regional, national, and finally local. In this context, therefore, UANESA hopes to establish contacts and links to gain technical and financial support from the following organizations and institutions on the basis of their commitment to UA development globally and regionally:

1. TUAN: The Urban Agriculture Network
2. IDRC: International Development and Research Centre
3. GFUA: Global Facility on Urban Agriculture
4. SGUA: Support Group on Urban Agriculture
5. FAO: Food and Agriculture Organization of the United Nations
6. UNDP: United Nations Development Programme
7. NRI: Natural Resources Institute (UK)
8. ETC: ETC-UA Programme via RUAF: Resource Centre for Urban Agriculture and Forestry (The Netherlands)
9. GTZ: German Agency for Technical Cooperation
10. UNCHS: United Nations Centre for Human Settlements (Habitat)
11. UWEP: Urban Waste Expertise Programme (The Netherlands/Kenya)
12. UNIFEM: United Nations Fund for Women (Nairobi)
13. SAHPF: South Africa Homeless Peoples Federation
14. CARE: Cooperative for America Relief Everywhere (Tanzania, Kenya, Uganda, Zimbabwe, South Africa, etc.)
15. FSDA: Foundation for Sustainable Development in Africa (Kenyan NGO)
16. FF: The Ford Foundation (Regional Chairs)
18. RELMA: Regional Land Management Unit (Nairobi)
19. etc.: Several other local ministries, departments, NGOs and CBOs in the region

The funding of the West and Central African network could be assured through subsidies and projects of members. However, lobbying can help to create a special fund for UA (e.g. with support of IDRC/FAO/WB/UNDP). In addition, the network can postulate calls for proposals, propose network members' expertise for UA studies and research missions. Other potential sources of financing are joining fees and members' yearly subscriptions.

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Research and Development Priorities

P. Drechsel¹ and D. Kunze²

¹IWMI (formerly of IBSRAM), Ghana Subregional Office for West Africa, Kumasi, Ghana; ²FAO of the United Nations, Regional Office for Africa, Accra, Ghana

A number of issues related to urban and peri-urban agriculture (UPA) and its resource base will arise in the near future. The following discussion¹ looks at a variety of aspects related to UPA and waste management. The chapter highlights: (i) issues related to environment and public health; (ii) scientific knowledge gaps in soil fertility management and nutrient recycling; (iii) decision-making in policy, planning and economics; and (iv) issues that are felt to be important topics from a farmer's point of view.

Some priorities concern '*development*', i.e. they focus on areas for projects or technical assistance at the field level. Priorities for '*research*', on the other hand, look at knowledge gaps that hinder ongoing development activities or future technical cooperation. At the same time research will build up a basis for decision-makers in policy and planning.

It has to be noted that necessary improvements in urban living, regarding agriculture as well as waste management, can only be made if decision-makers are willing to take the first steps. Many activities discussed below depend on the outcome of a number of general decisions, which have to be taken at the policy level.

For agriculture, one of the major decisions to be made at policy and planning levels is the appropriate consideration of UPA by the municipal authorities. In most cities in western Africa this process is still in its development, leaving the status of urban and peri-urban agriculturists, who are often squatters, unclear. These farmers are not only denied any official status, but refused any governmental service as well. However, there are

¹The chapter summarizes results of four working groups established in the course of the IBSRAM-FAO workshop on urban and peri-urban agriculture in Accra, 1999.

also encouraging examples of support as mentioned in the Introduction to this book.

Regarding waste management, one of the major decisions to be taken at the level of policy and planning is the allocation of sites for waste deposits and treatment, and the organization and finance of waste collection. Moreover, the control of illegal dumping or 'hijacking' of trucks transporting night-soil (Owusu-Bennoah and Visker, 1994) needs attention. The free accessibility of 'composted waste' from illegal waste dumps undermines not only sanitation but also any controlled and environmentally safe compost production, which, however, cannot produce a product free of charge.

Environment and Public Health

There are potential risks for the environment and public health that may arise in relation to (peri-)urban agriculture (cf. Birley and Lock, 1999). These may be caused through the use of waste water, pesticides, recycled waste-stream products (compost from sewage, manure, etc.), and by handling through marketing, hence four areas of sanitation are concerned: infrastructure, water, soil, food and nutrition.

Priority areas for projects or technical assistance concerning *infrastructure* include:

- educational campaigns on environmental health with regard to the use of drains, latrines, market facilities, food handling, waste dumps and other infrastructures available;
- the improvement of market facilities concerning access to safe water, latrines and distinct garbage disposal sites;
- city planning with attention to environmentally safe areas for UPA to avoid illegal dumping as well as properly planned landfill sites;
- institutionalized collaboration between administration and projects working on sanitation on the one hand and actors in urban agriculture on the other.

For *water*, as a major resource of urban and peri-urban livelihoods, the following priority areas can be identified:

- Safe agricultural production should be encouraged, with focus on institutionalized water quality monitoring (including agrochemicals where necessary) and certification programmes, which should be transparent for the farmers. Sources of pollution should be located and legal disincentives for point-source polluting industries should be addressed such as car wash facilities.
- The options of community-based water management in urban and peri-urban areas with simple community-based water treatment technology should be explored.
- Sustainable use of lowlands or bottomlands should be promoted; including: (i) ecological and hydrological impact studies of UPA in bottomlands; and (ii) participatory technology development for UPA in bottomlands.

Priority areas for *soil* conservation focus mainly on increasing awareness and familiarity within the farm and non-farm community. They should centre on activities to:

- increase the (community) knowledge-base on soil fertility decline and soil contamination in peri-urban farming systems;
- increase the knowledge-base on the safe use of compost and adequate application methods, including the monitoring of pathogenic contamination due to the use of compost that has not matured.

Food nutritional aspects concern the following areas:

- raising the level of awareness on food (re-)contamination by producers and all actors in marketing, such as transporters, retailers, market people;
- fixing and monitoring critical levels of agrochemicals, bacteriological contamination, etc. in food – and support of institutional monitoring programmes therein.

Nutrient Recycling

Soil fertility aspects are of major concern to research with respect to sustainable soil management, maintaining productivity for agricultural production and environmental protection against soil contamination. Most discussed vis à vis peri-urban agriculture is nutrient mining that takes place in farmers' fields versus the role that compost and other waste-stream products may play as nutrient sources.

There is a need to understand nutrient flows in existing (peri-)urban farming systems which is supported by establishing typologies of farming systems, mapping the various nutrient flows in different farming systems, and determining the attitudes, perceptions, and demand for waste-stream products for soil fertility improvement within different farming systems.

In a second step the amounts and value of urban waste materials available need to be quantified and their agricultural potential assessed. Here, scientific research and farmers' experimentation on the effects of using waste materials as inputs should be combined. This includes investigating:

- different storage options, application rates, and mixtures;
- long-term benefits other than the short-term fertilizing value (this may require methodology development);
- short- and long-term negative effects on soil quality/fertility;
- specific applications for different crops.

In a third step, appropriate waste processing technologies can be developed subsequently and tested for a range of purposes that are sustainable, given current resource constraints.

Finally, improved research uptake and promotion pathways should be elaborated and encouraged within and by the respective governmental and

non-governmental institutions. Besides research, institutional policy and fiscal issues are of paramount importance in determining the potential use of waste-stream products such as municipal solid waste, especially with regard to cost–benefit analysis of waste management/recycling options. Researchable constraints in this area need to be further identified.

There is a major gap in the dissemination and extension of existing knowledge and research findings in the area of urban and peri-urban issues. Therefore the need to ensure that appropriate and effective uptake pathways are incorporated into any research initiatives has to be pointed out. Development initiatives would then require the training and support of extension services.

Policy, Planning and Economics

What are the constraints to the use of waste-stream products in UPA with regard to policy regulations, planning priorities, as well as logistic, technical or economic shortcomings? A range of constraints to urban agriculture and organic waste recycling can be identified and related solutions that should become objectives of technical assistance or human capacity-building projects have been suggested:

1. Increase public awareness and improve implementation of by-laws, technical directives, health orders, etc. as well as more information on organic waste recycling options and opportunities.
2. Promote institutional capacity-building on strategic and integrated planning towards sustainable urban development and food security carried out with consideration of (peri-)urban agriculture in the planning process, with consideration of the economics of organic waste management, with participation of stakeholders in the (land) planning process, with consideration of research outputs related to waste recycling and adoption already at hand, and with the use of advanced tools, such as geographic information system, for city development/planning.
3. Improve infrastructure (financial, physical, personnel, and institutional).
4. Identify feasible and appropriate technologies and equipment, which are transferable to local conditions and easy to maintain, but as effective as possible with respect to nutrient recycling, sanitation and public health.
5. Enhance investment in UPA and waste management/recycling programmes by improving awareness and financial support for UPA, expanding awareness and markets for composted products. A cost–benefit analysis of urban agricultural products is required as well as cost recovery studies on waste management.

Several of the issues discussed in this section will be challenges to municipal and peri-urban decision-making. Although UPA brings a certain risk to the urban population, because of the use of unsafe water or a relatively high

application rate of pesticides, there is no reason to believe that agricultural products from other areas do not carry a similar or other risks. A favourable aspect of UPA and compost production is that they reduce the volume of waste that would otherwise pose a problem to the cities and generate an even higher risk to human beings and the environment. Additionally, legal and illegal dumping sites influence the general appearance of a city considerably and those relying on tourism as a source of income cannot afford to abstain from action in this field for long.

Farmers' Points of View

Farmer representatives were asked to identify constraints and recommendations for UPA development based on their experiences and views. They came from various backgrounds such as vegetable or livestock production, small- or medium-scale farming and expressed a number of priority concerns that they were facing such as:

- land accessibility and availability (urban) as well as land tenure (peri-urban);
- credit availability – timing and disbursement of funds, high interest rates, acquisition of loans (without collateral), etc.;
- little knowledge and high costs of agrochemicals as well as poor distribution/access;
- transport of organic manures/compost (too bulky and costly);
- water availability/accessibility (costs) and quality;
- market entry, price fluctuation and insufficient access to marketing information;
- insufficient number of extension officers, with no training on UPA issues and low frequency of contact.

It has to be stated that, while the need for inputs was stressed, decline in soil fertility or land degradation as well as labour shortage and the postharvest sector were noticed but ranked among the less pressing or obvious problems.

Farmers' main concerns were directed towards more information and better education. Topics such as 'integrated nutrient management' and 'integrated pest management' as well as training on the safe use of agrochemicals and capacity-building in marketing and business were frequently mentioned. Also the integration of UPA or home gardening into school curricula was recommended.

Several of the issues highlighted by the farmer representatives were also stressed by other working groups, such as the need for information on the different waste-stream products, their availability, quality, handling and application, or the need for more information on water quality. It was generally recognized that the issues and points made are interrelated. Moreover, problems related to the access to land and credit were recognized mutually.

However, the farmers stressed, more than the other groups, the inappropriate education of extension officers concerning the problems, requirements, market dynamics and related options and opportunities of UPA. Farmers' field schools were identified as a possible tool that might help close the information gaps identified. On the other hand, farmers showed (naturally) little interest in the typology of farming systems, nutrient flows within farming systems, or an analysis of their perceptions of waste-stream products and willingness to use them (which was, as the discussion revealed, unanimously high, even for composted night-soil although not for every crop).

Urban living is becoming more and more complex as urban centres grow rapidly. The urgency to make decisions regarding a number of issues raised in this chapter has become pressing. It is therefore imperative to invest in this field in the nearest future. As the significance of the issues will vary from city to city and country to country it will be important to find city-specific approaches linked to national and international programmes, initiatives, and support.

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